

US008137951B2

(12) **United States Patent**
Sloma et al.(10) **Patent No.:** **US 8,137,951 B2**
(45) **Date of Patent:** **Mar. 20, 2012**(54) **METHODS FOR PRODUCING HYALURONAN
IN A RECOMBINANT HOST CELL**(75) Inventors: **Alan Sloma**, Davis, CA (US); **Leslie Naggiar**, legal representative, Suffern, NY (US); **Regine Behr**, Roseville, CA (US); **William Widner**, Davis, CA (US); **Maria Tang**, Fairfield, CA (US); **David Sternberg**, Davis, CA (US); **Linda Sternberg**, legal representative, Davis, CA (US); **Stephen Brown**, Davis, CA (US)(73) Assignee: **Novozymes, Inc.**, Davis, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/084,230**(22) Filed: **Apr. 11, 2011**(65) **Prior Publication Data**

US 2011/0189737 A1 Aug. 4, 2011

Related U.S. Application Data

(62) Division of application No. 12/891,548, filed on Sep. 27, 2010, which is a division of application No. 10/326,185, filed on Dec. 20, 2002, now Pat. No. 7,811,806.

(60) Provisional application No. 60/342,644, filed on Dec. 21, 2001.

(51) **Int. Cl.****C12N 1/20** (2006.01)
C12N 15/74 (2006.01)
C12N 15/00 (2006.01)
C12P 21/00 (2006.01)
C12P 9/26 (2006.01)
C12P 1/00 (2006.01)
C12N 9/00 (2006.01)
C12N 9/24 (2006.01)
C12N 9/88 (2006.01)
C07H 21/04 (2006.01)(52) **U.S. Cl.** **435/252.31**; 435/252.3; 435/471; 435/320.1; 435/69.1; 435/101; 435/84; 435/41; 435/183; 435/200; 435/232; 536/23.2; 536/23.7(58) **Field of Classification Search** 435/252.31, 435/252.3, 471, 320.1, 69.1, 101, 84, 41, 435/183, 200, 232; 536/23.2, 23.7
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Primary Examiner — Ganapathirama Raghu(74) *Attorney, Agent, or Firm* — Robert L. Starnes(57) **ABSTRACT**The present invention relates to methods for producing a hyaluronic acid, comprising: (a) cultivating a *Bacillus* host cell under conditions suitable for production of the hyaluronic acid, wherein the *Bacillus* host cell comprises a nucleic acid construct comprising a hyaluronan synthase encoding sequence operably linked to a promoter sequence foreign to the hyaluronan synthase encoding sequence; and (b) recovering the hyaluronic acid from the cultivation medium. The present invention also relates to an isolated nucleic acid sequence encoding a hyaluronan synthase operon comprising a hyaluronan synthase gene and a UDP-glucose 6-dehydrogenase gene, and optionally one or more genes selected from the group consisting of a UDP-glucose pyrophosphorylase gene, UDP-N-acetylglucosamine pyrophosphorylase gene, and glucose-6-phosphate isomerase gene. The present invention also relates to isolated nucleic acid sequences encoding a UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, and UDP-N-acetylglucosamine pyrophosphorylase.**23 Claims, 45 Drawing Sheets**

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Hyaluronic acid

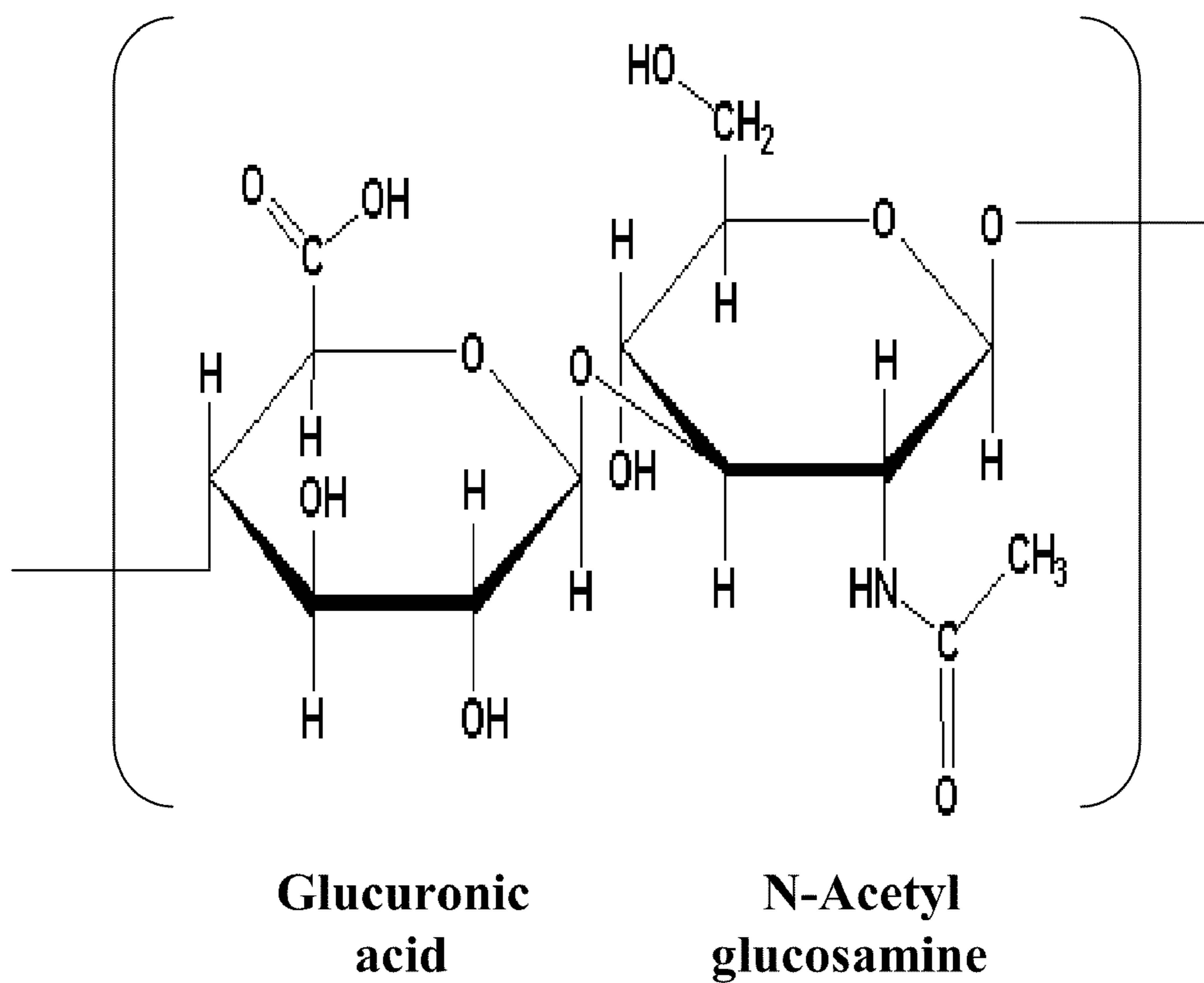


Fig. 1

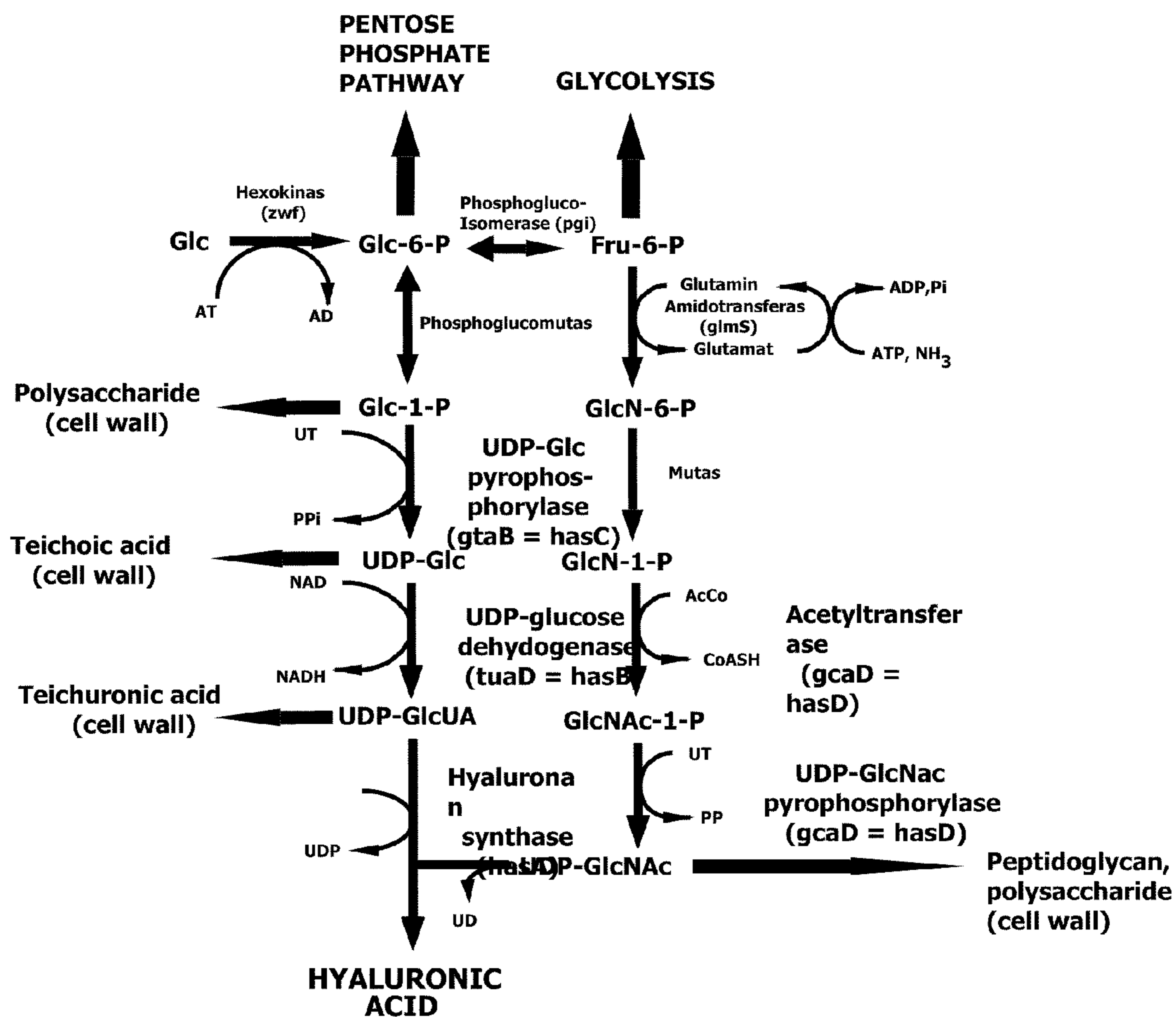


Fig. 2

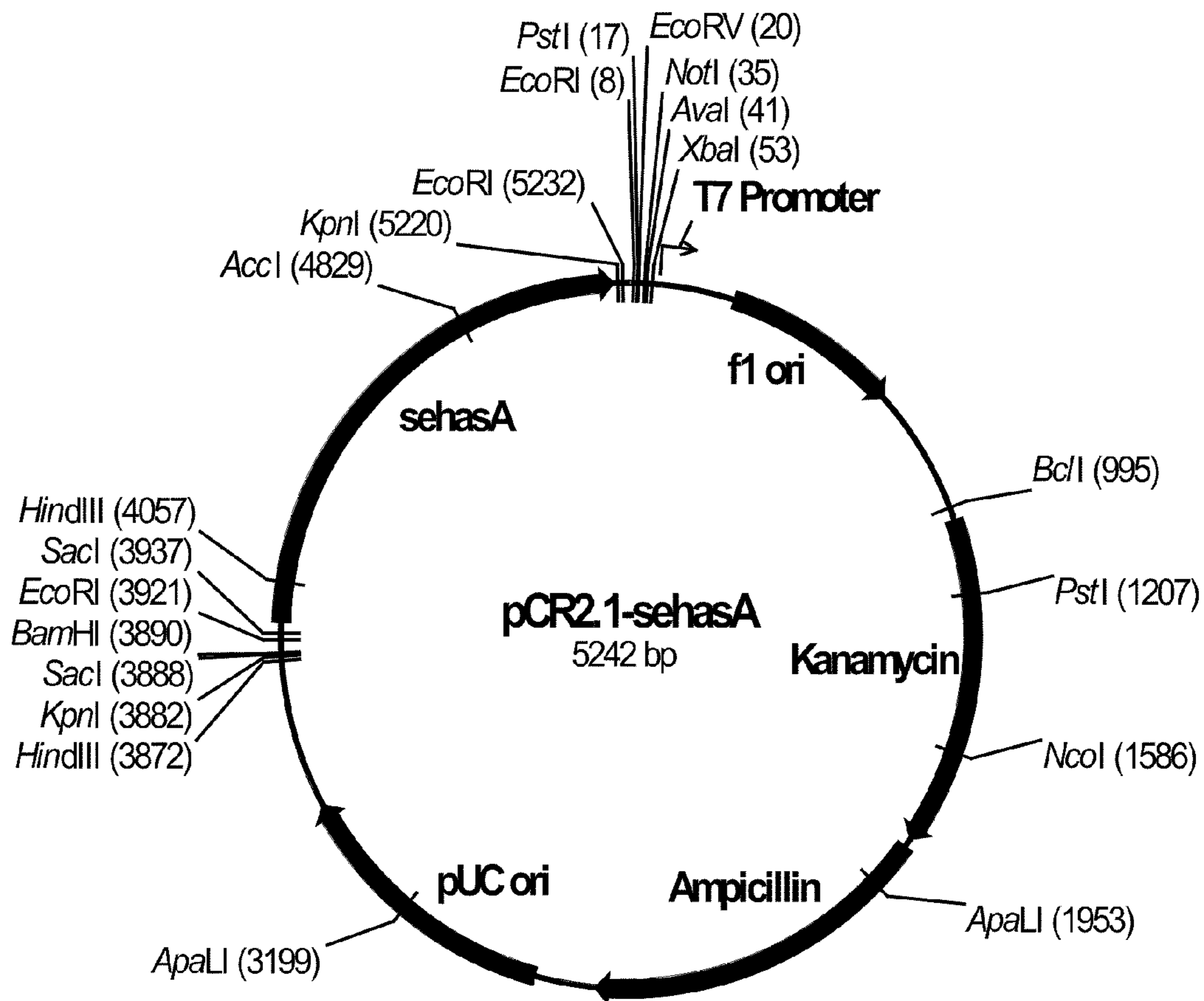


Fig. 3

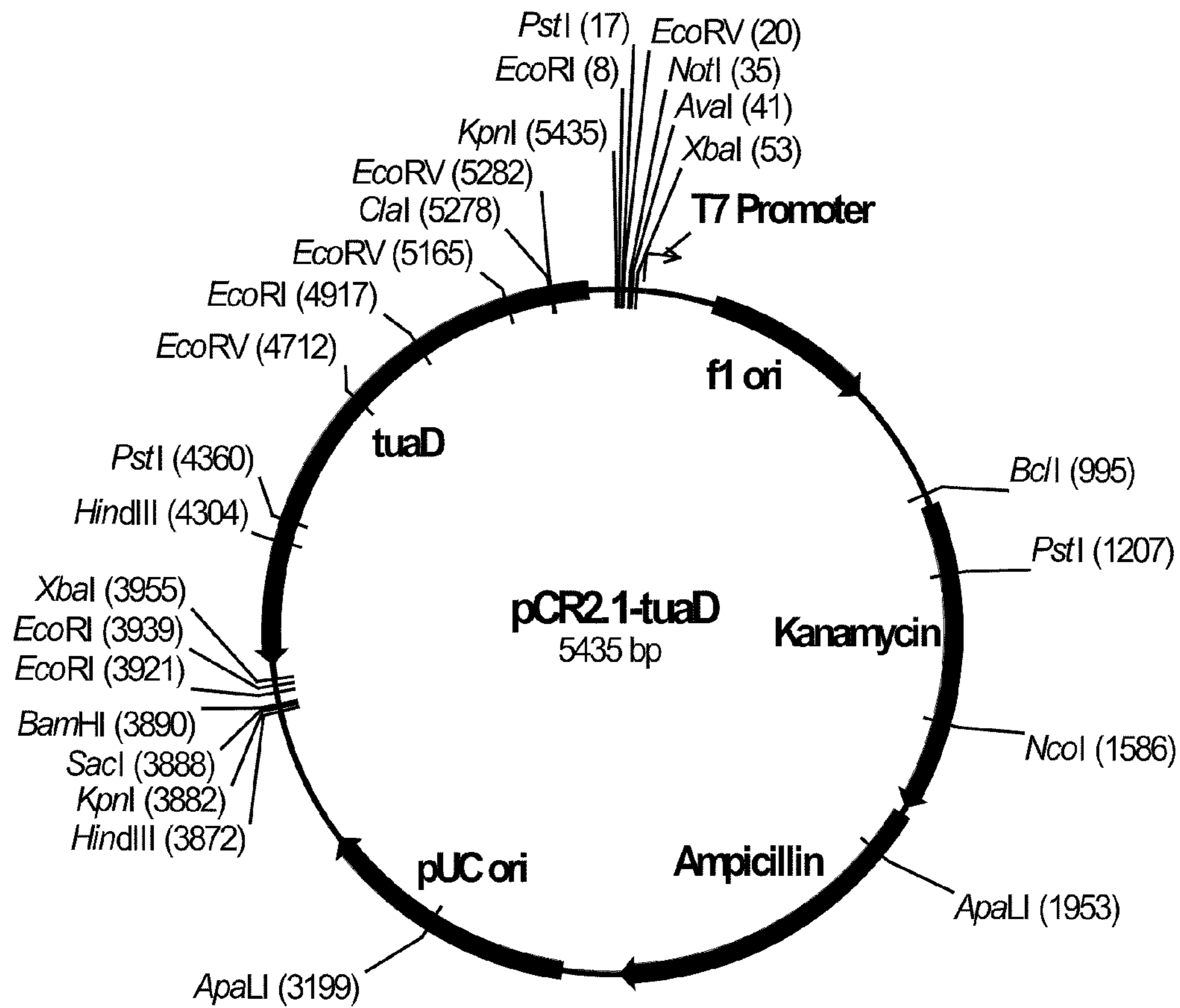


Fig. 4

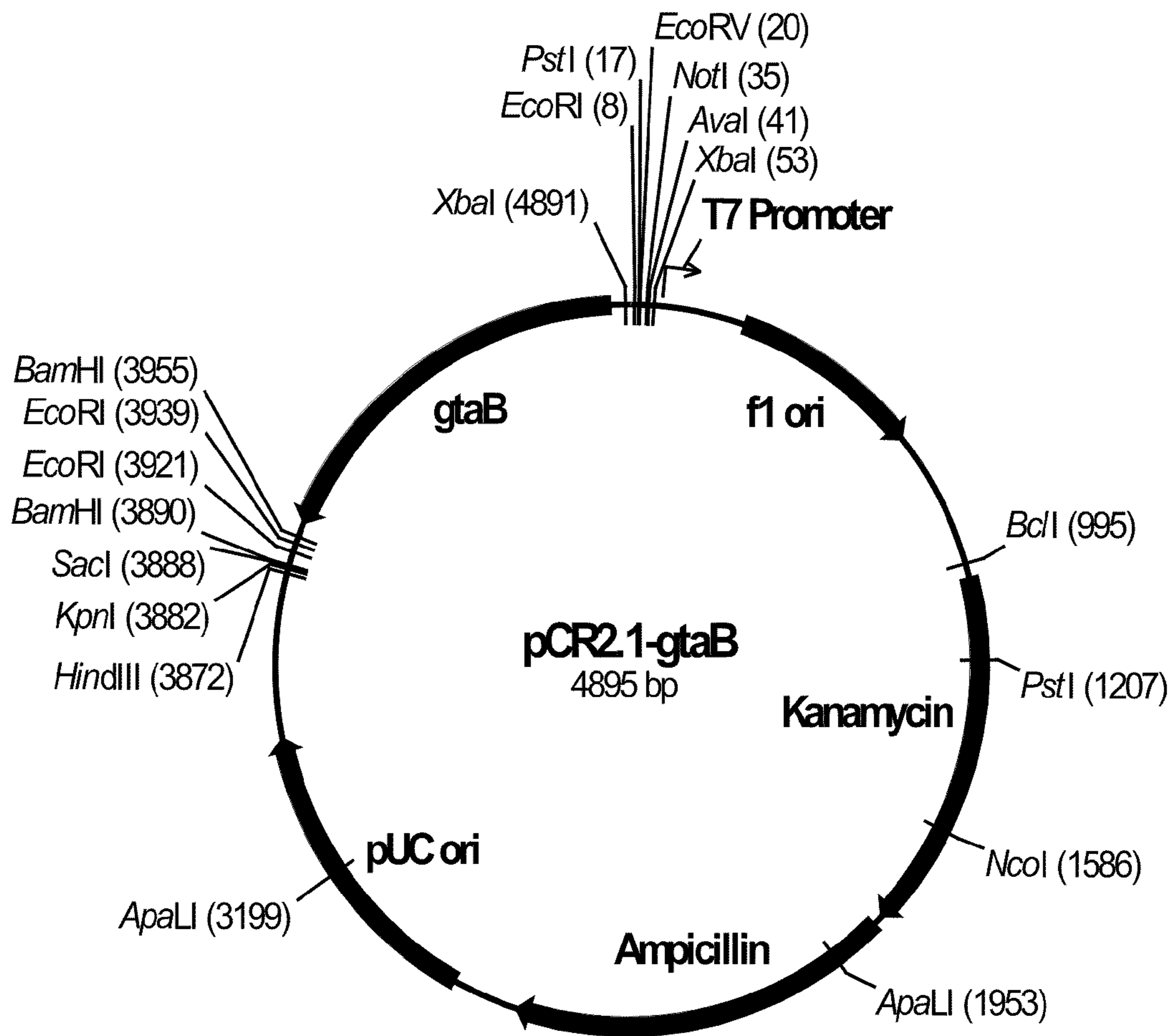


Fig. 5

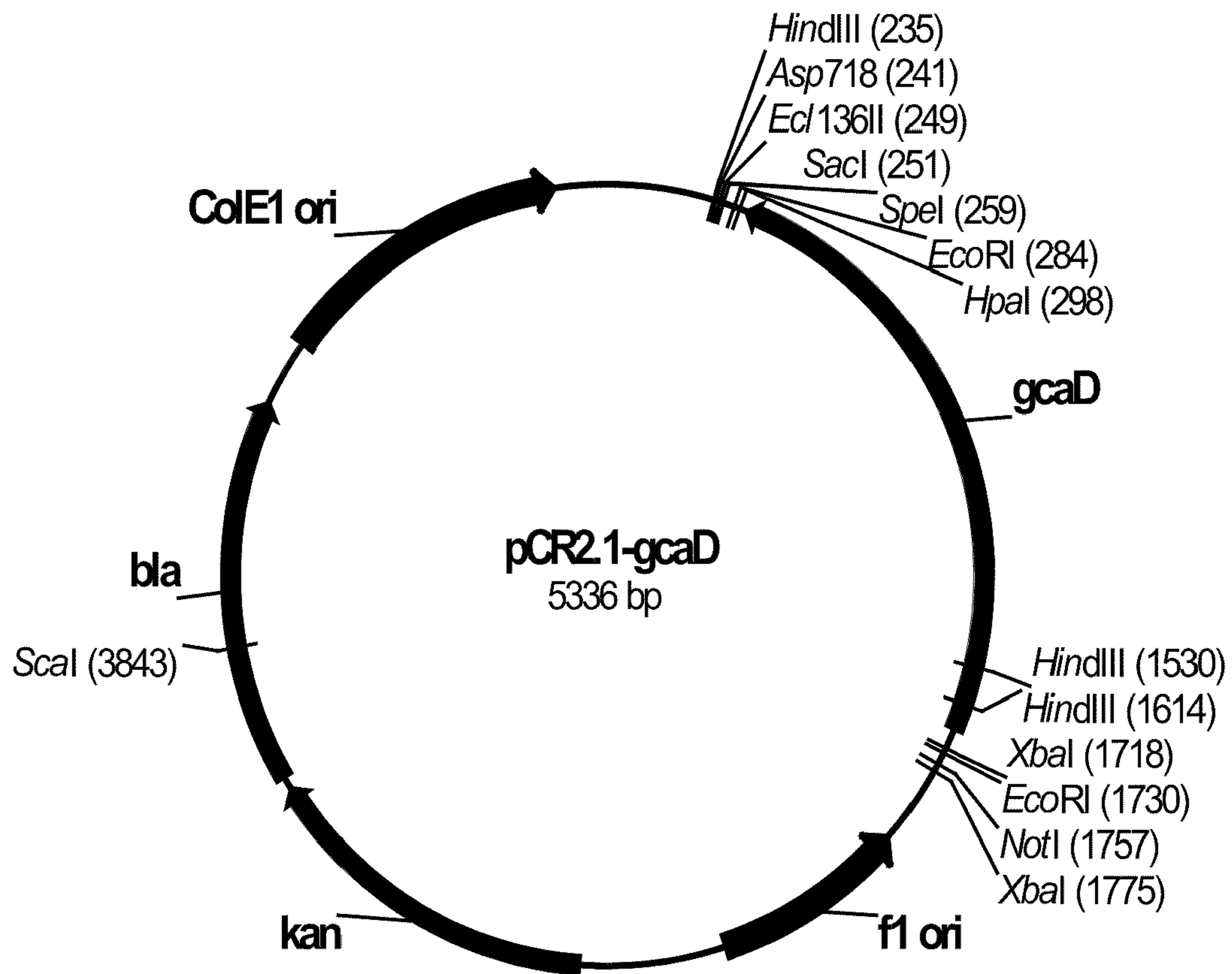


Fig. 6

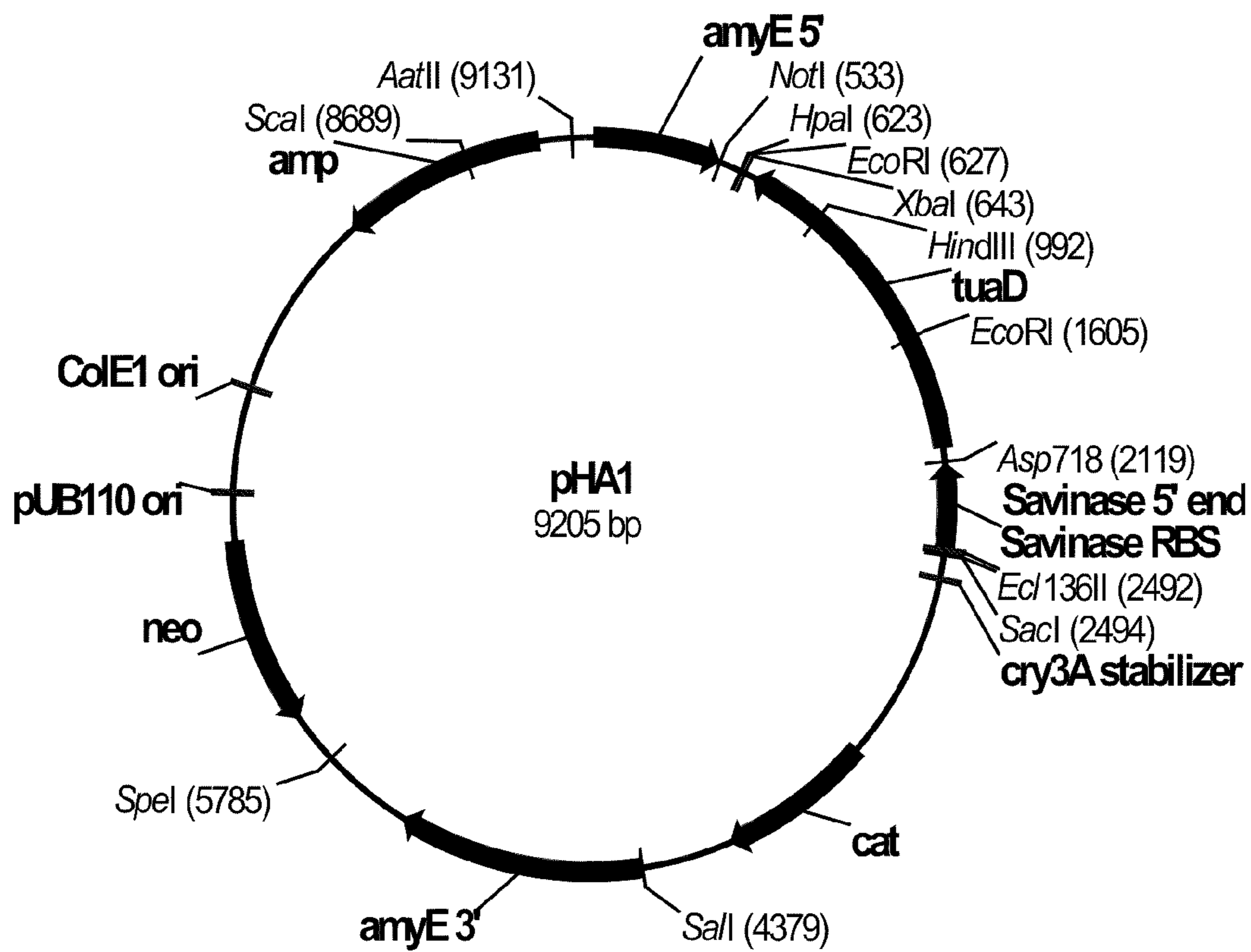


Fig. 7

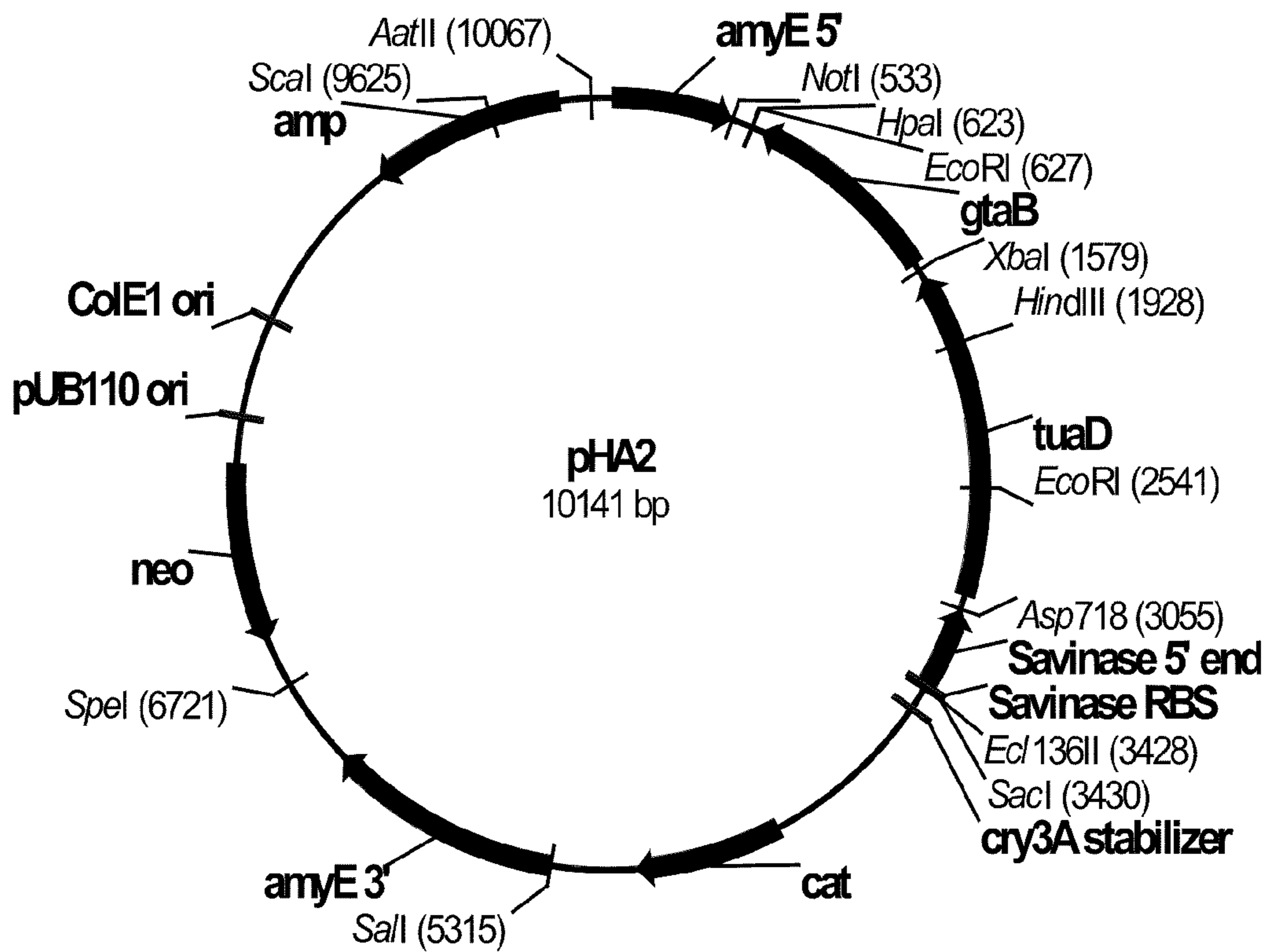


Fig. 8

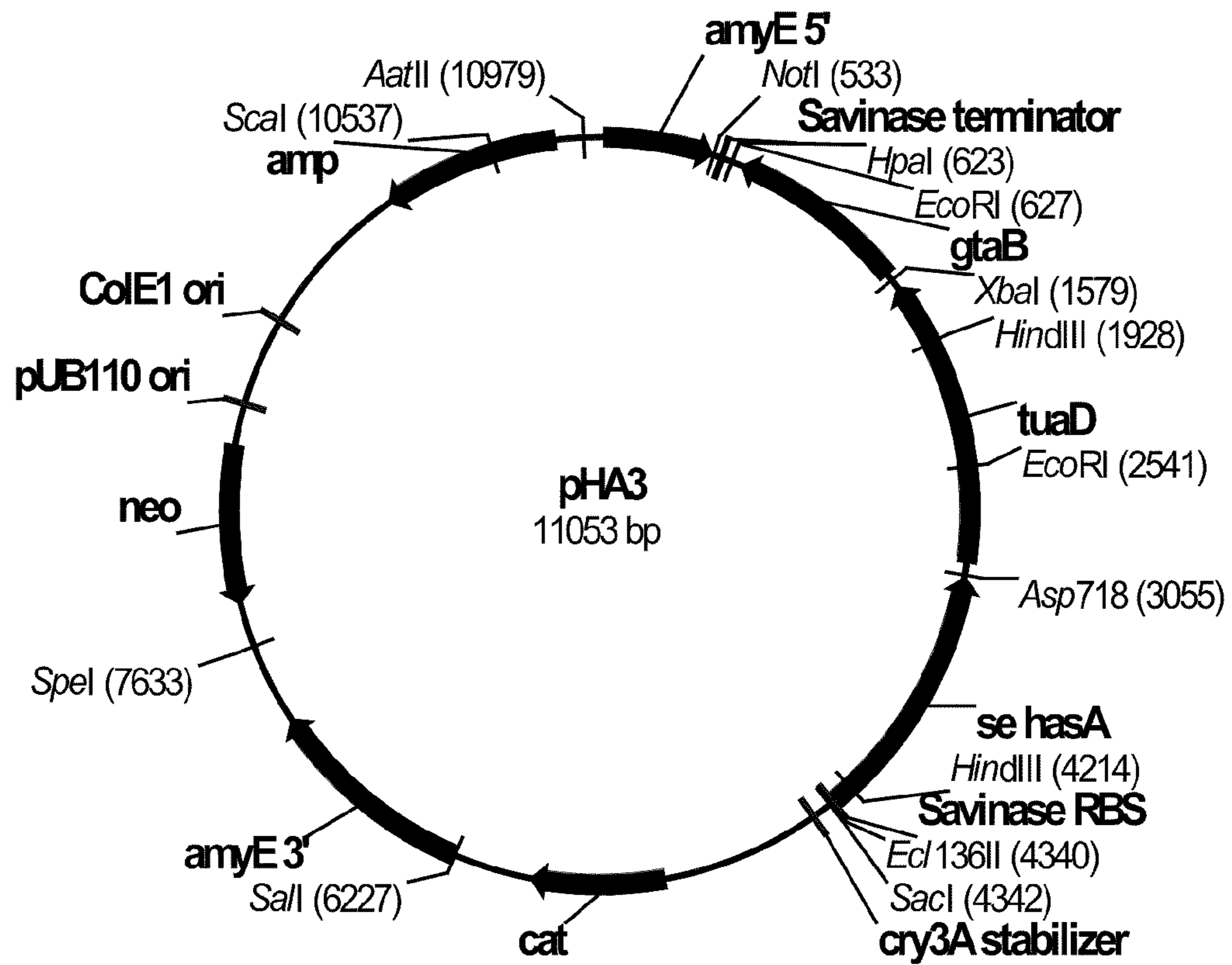


Fig. 9

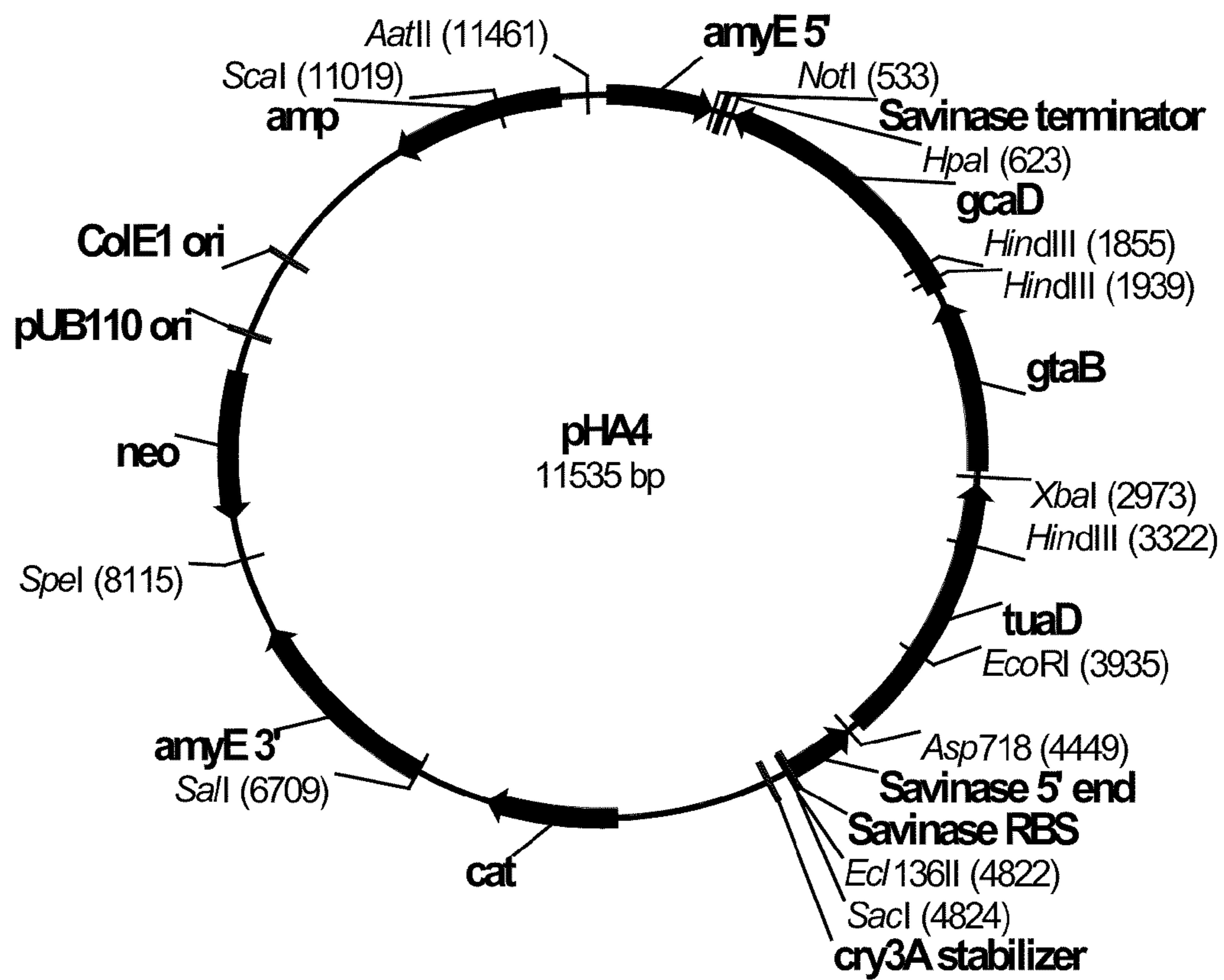


Fig. 10

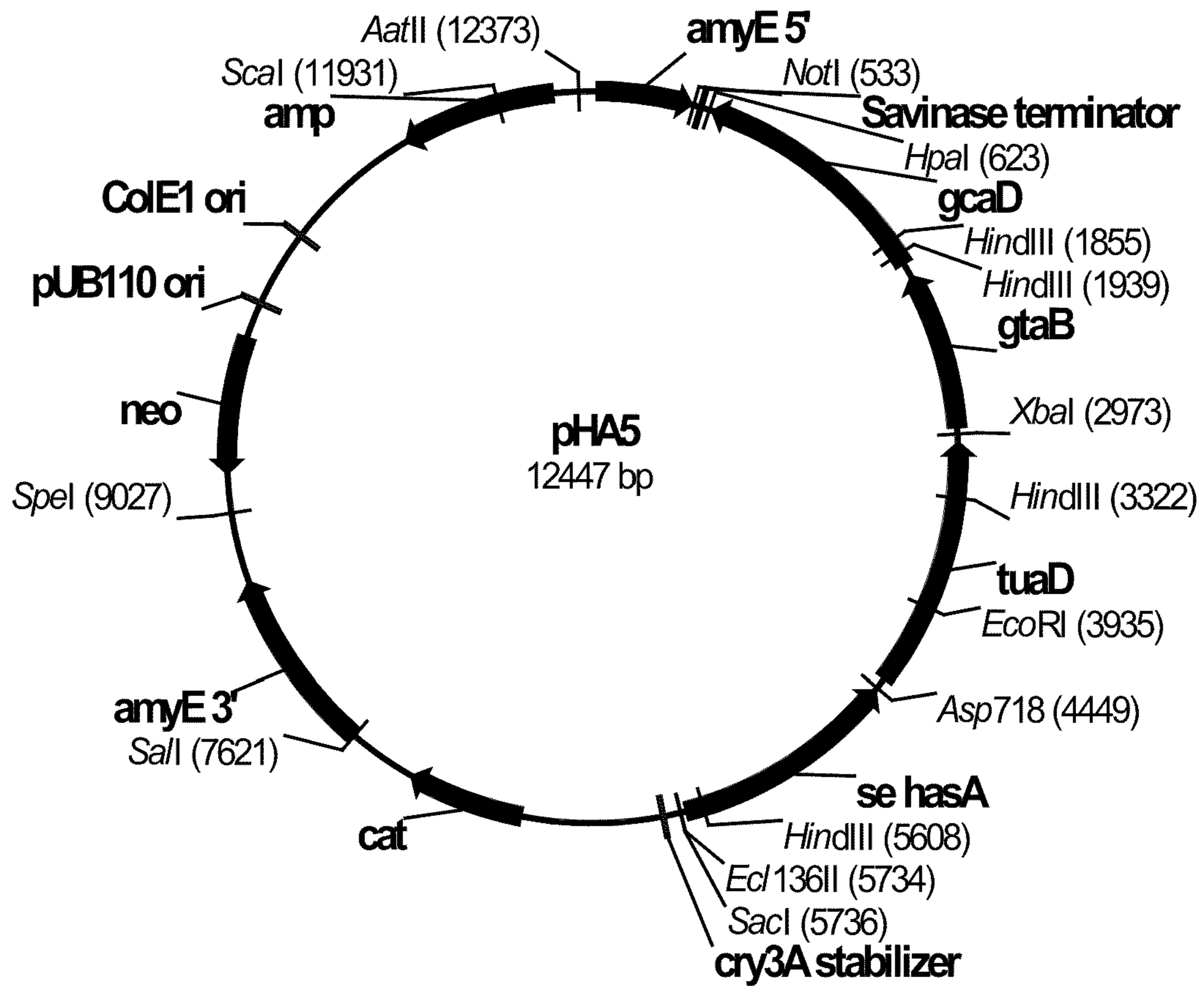


Fig. 11

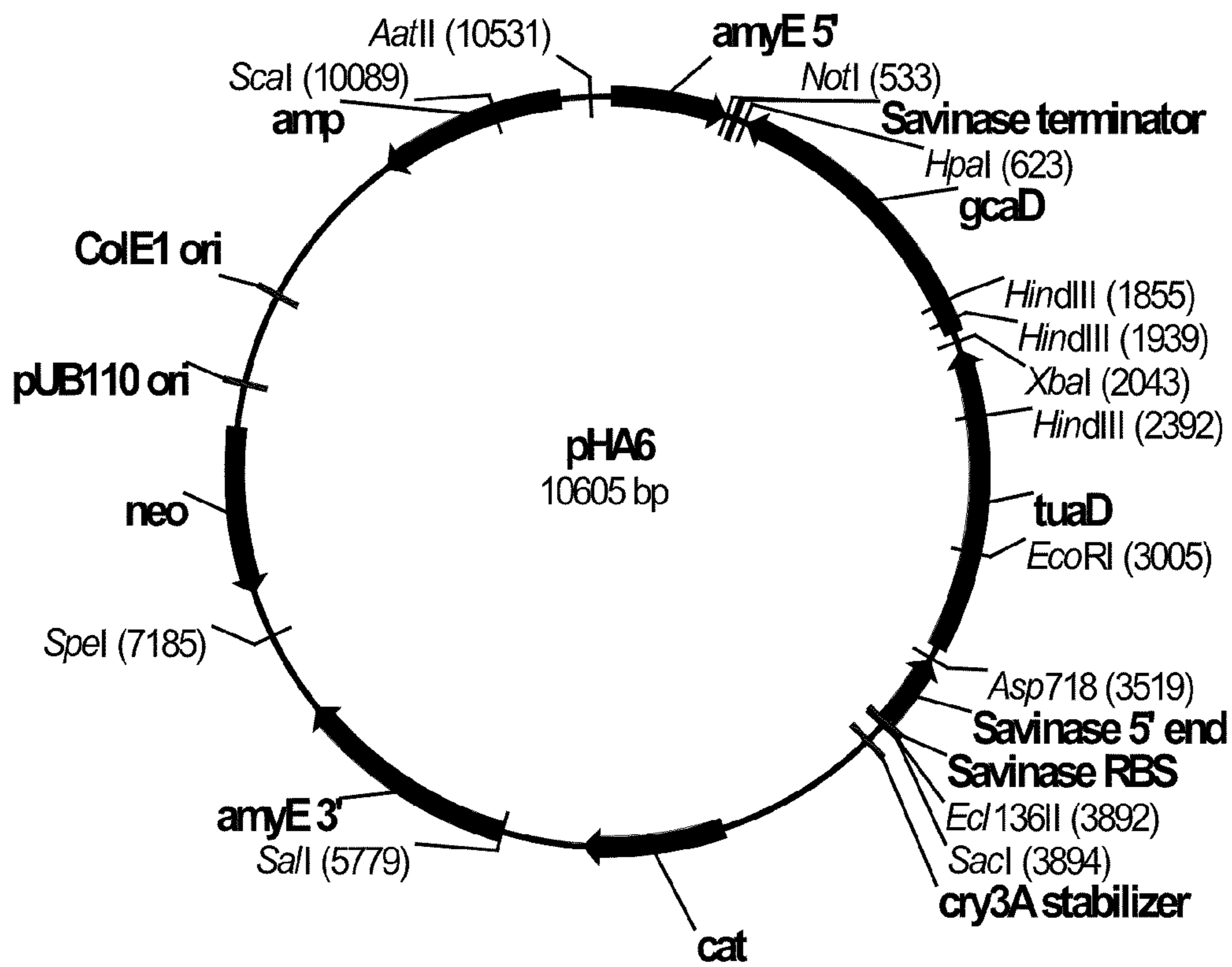


Fig. 12

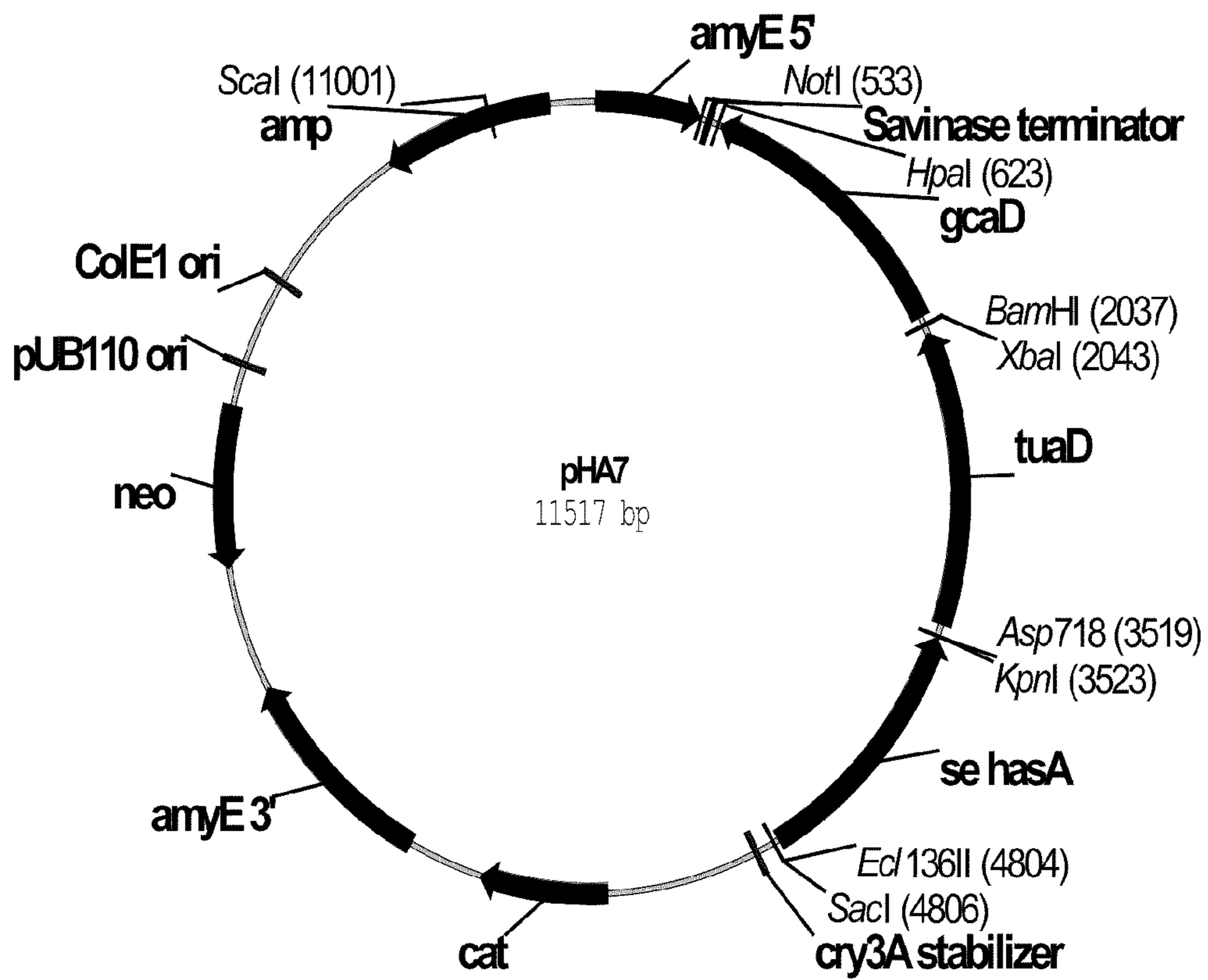


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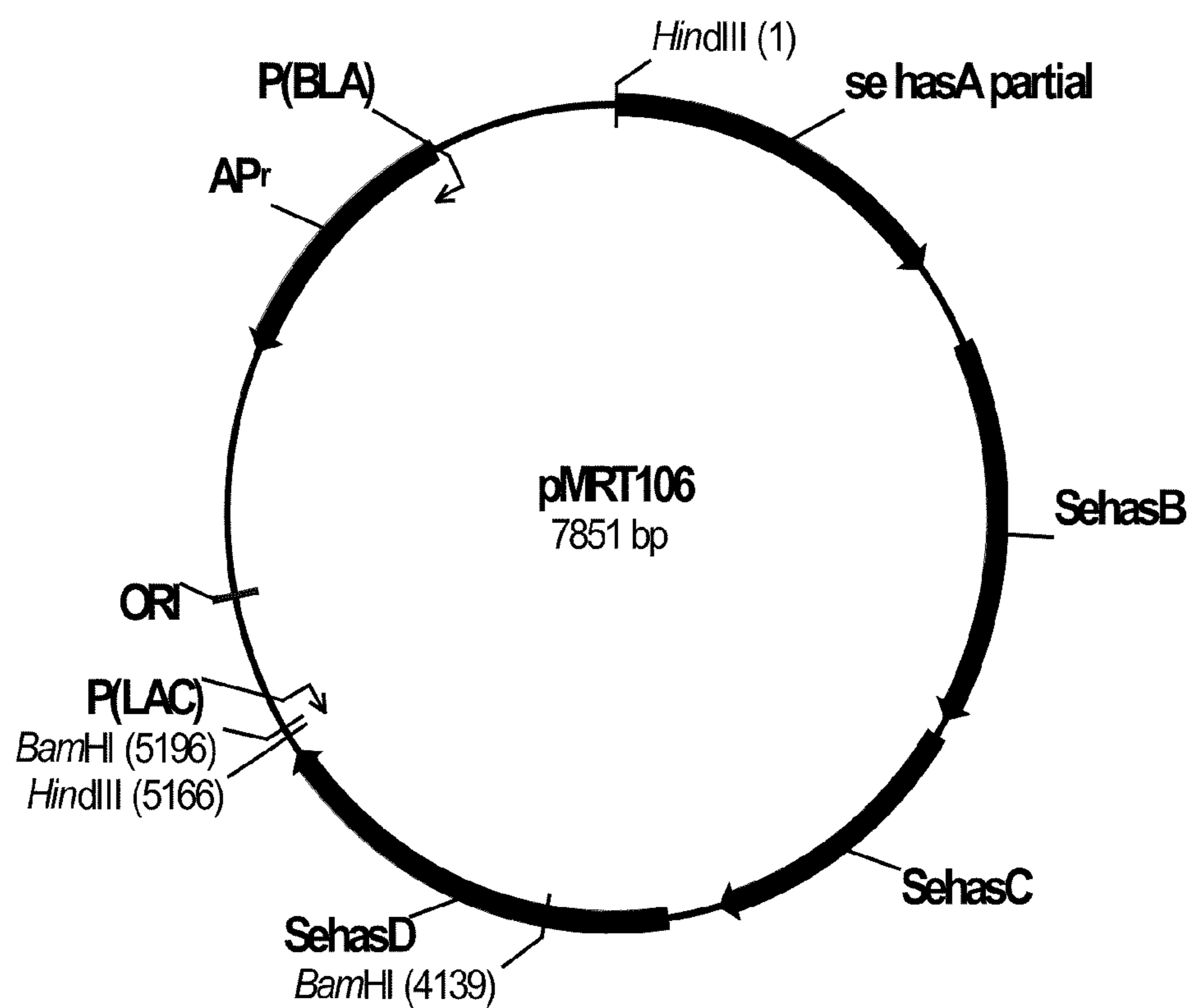


Fig. 14

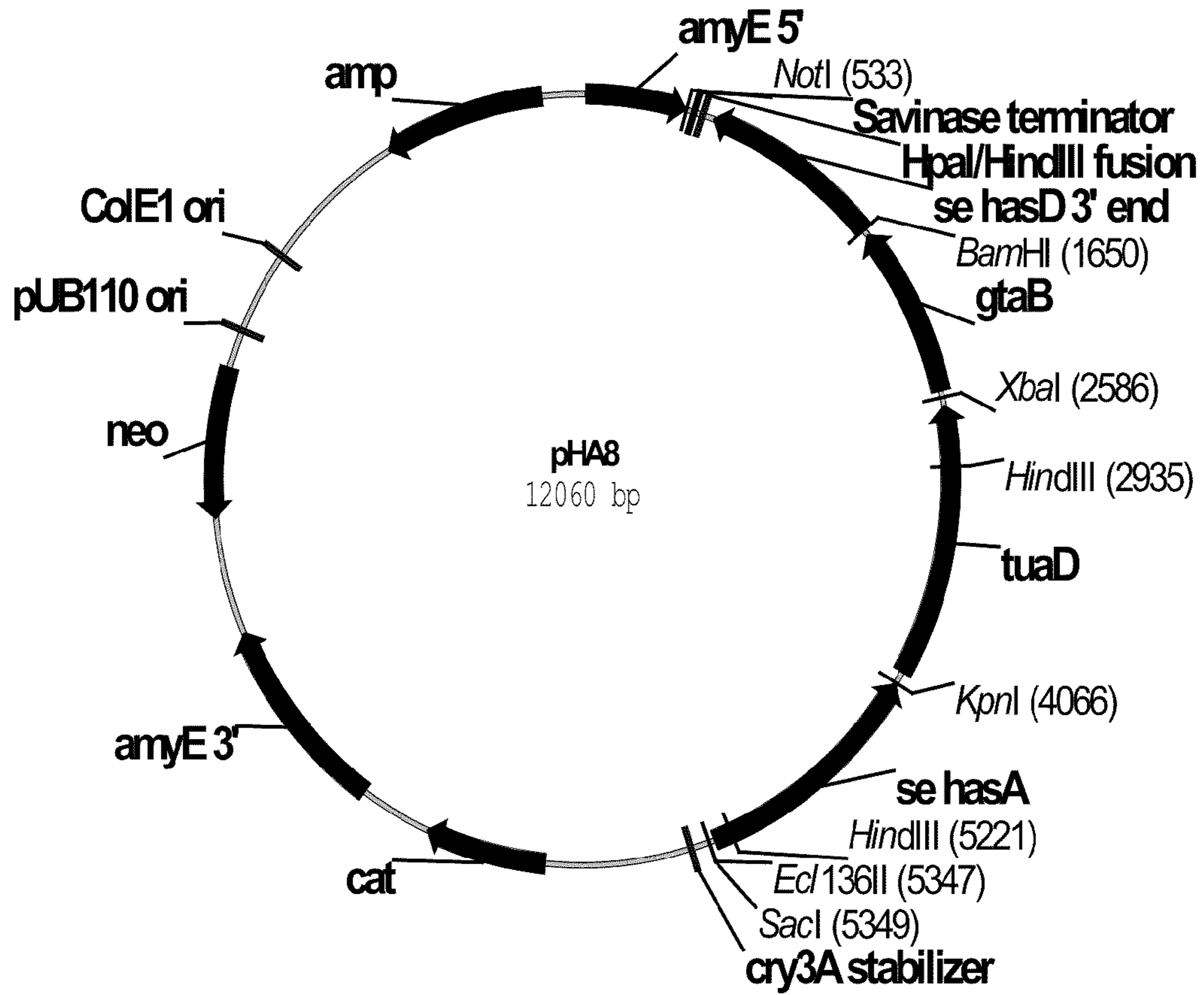


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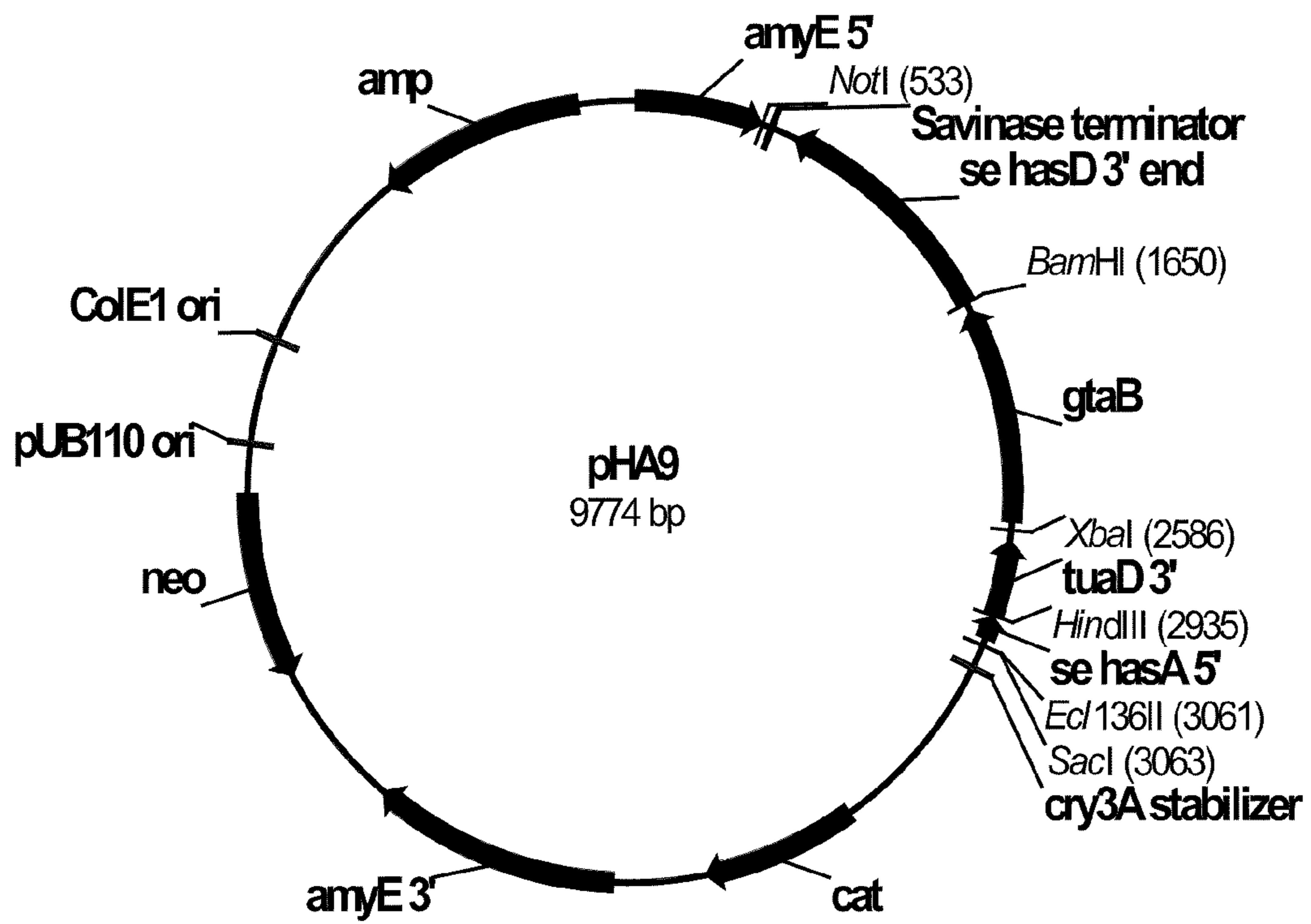


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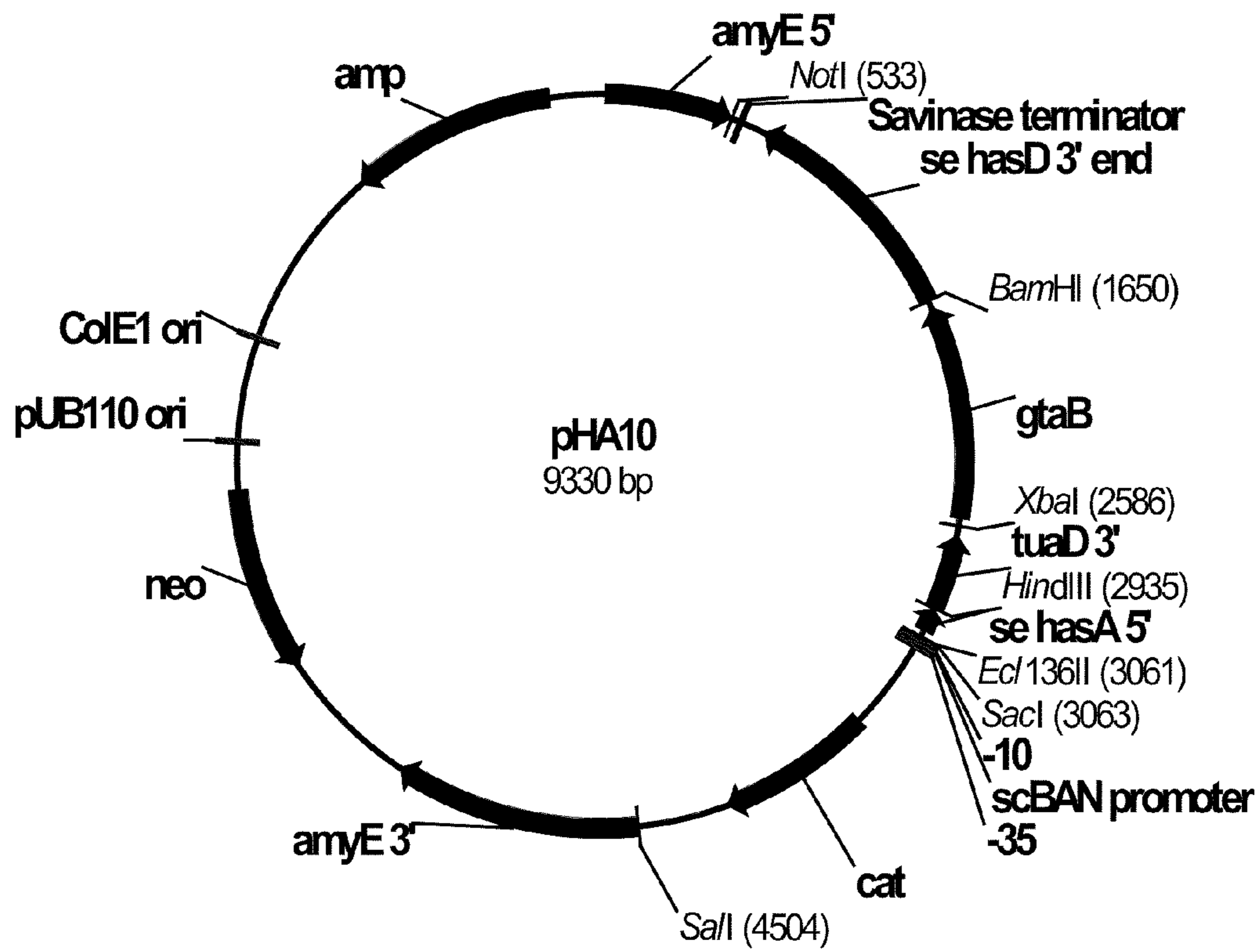


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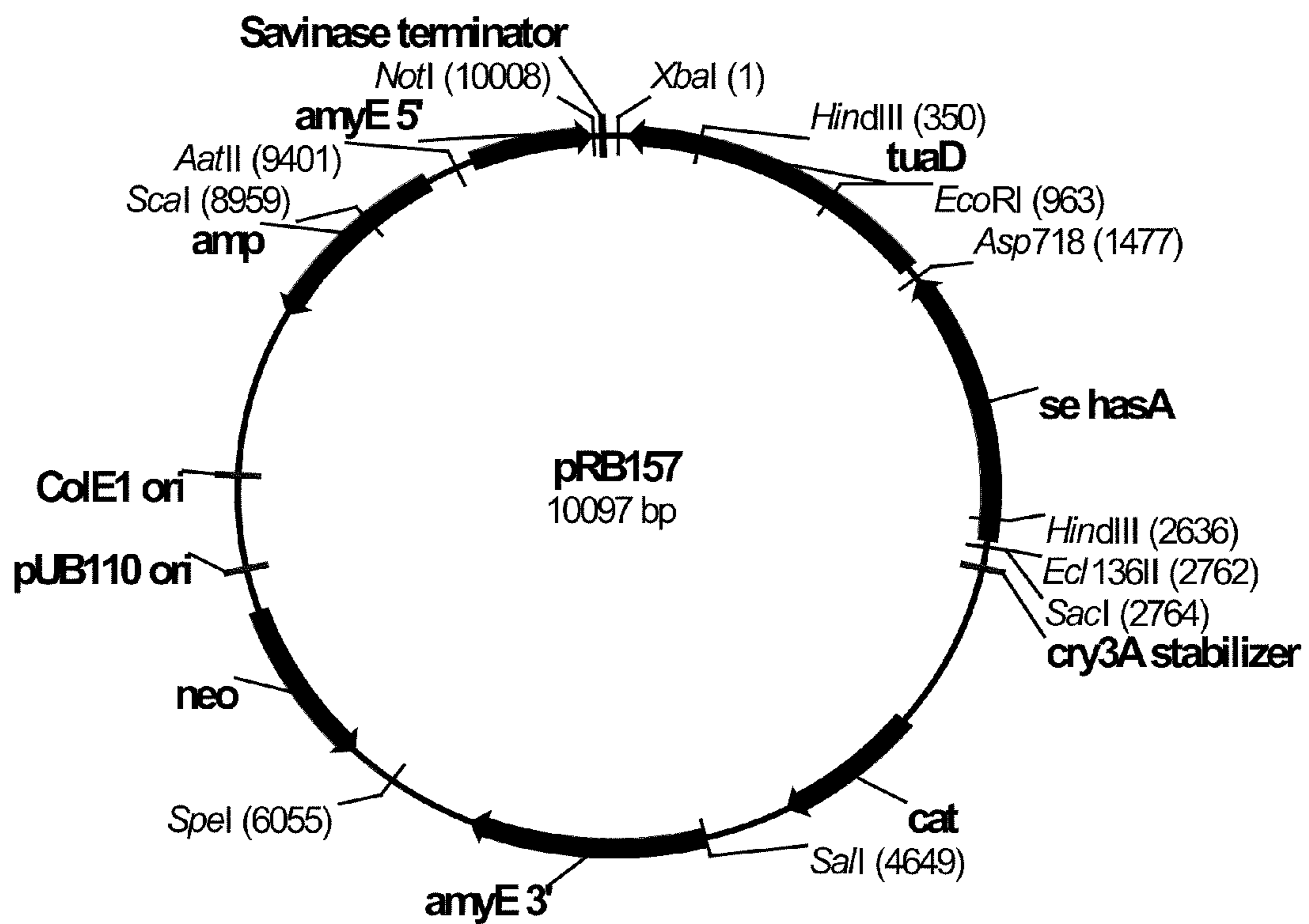


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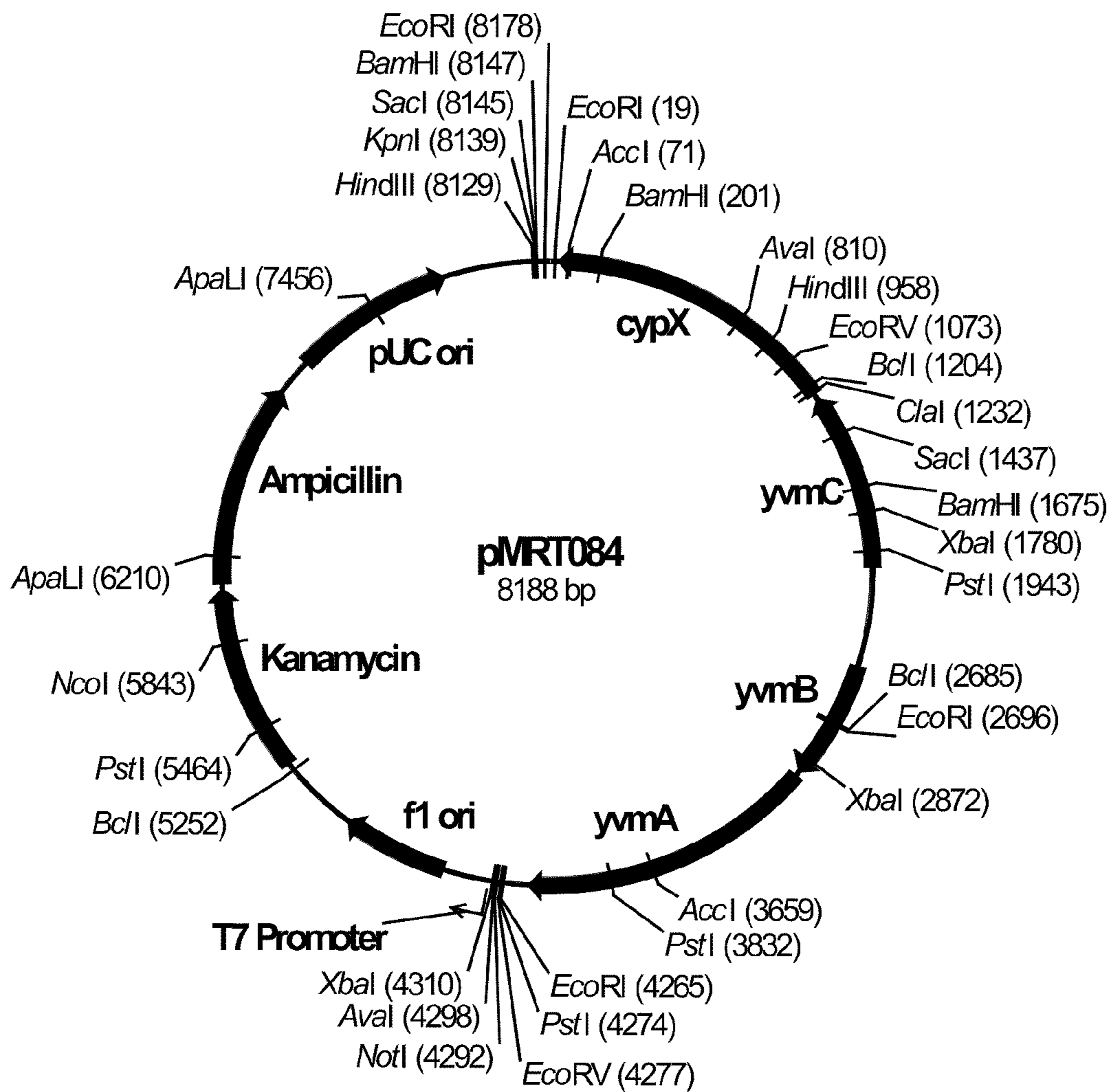


Fig. 19

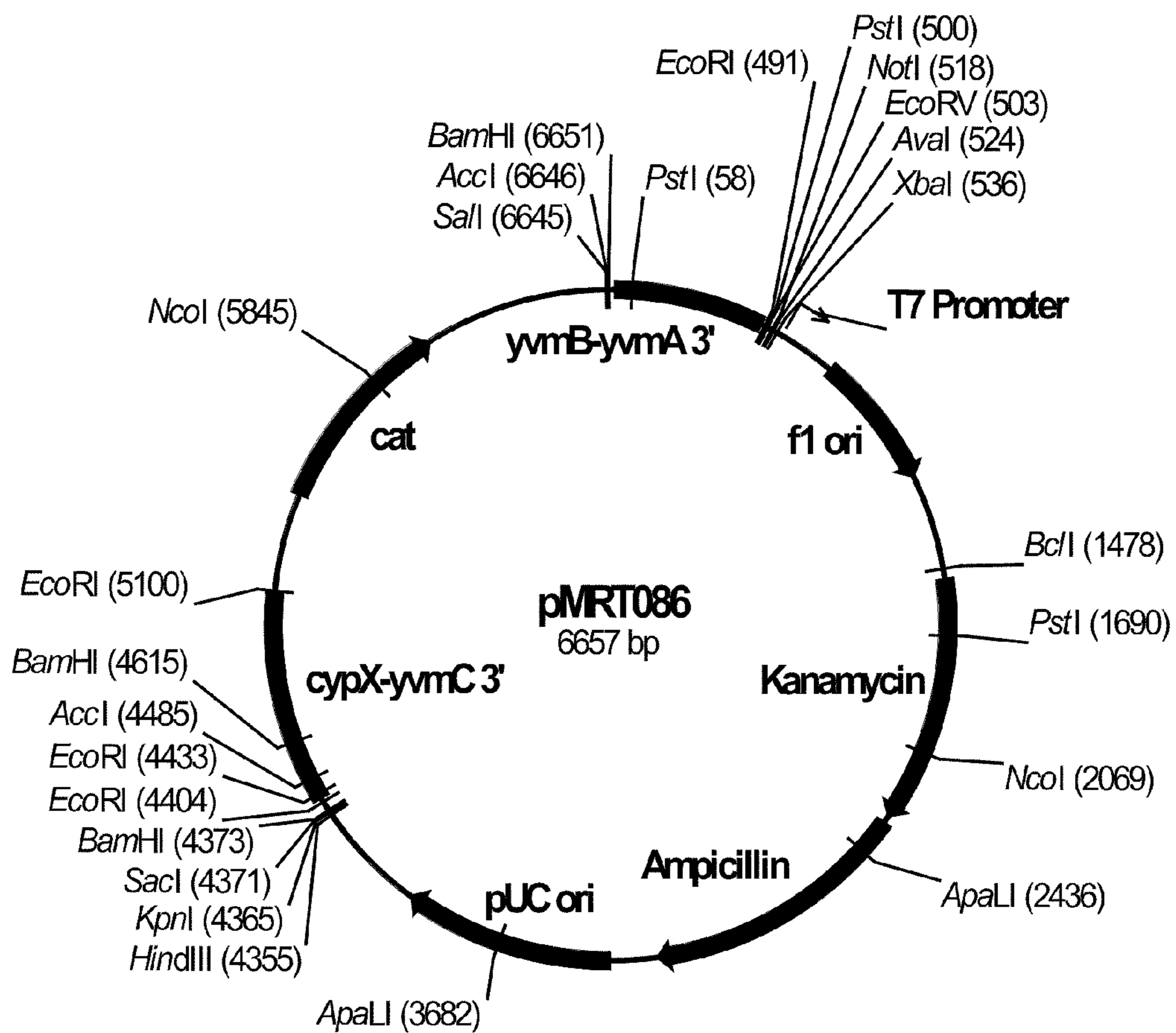


Fig. 20

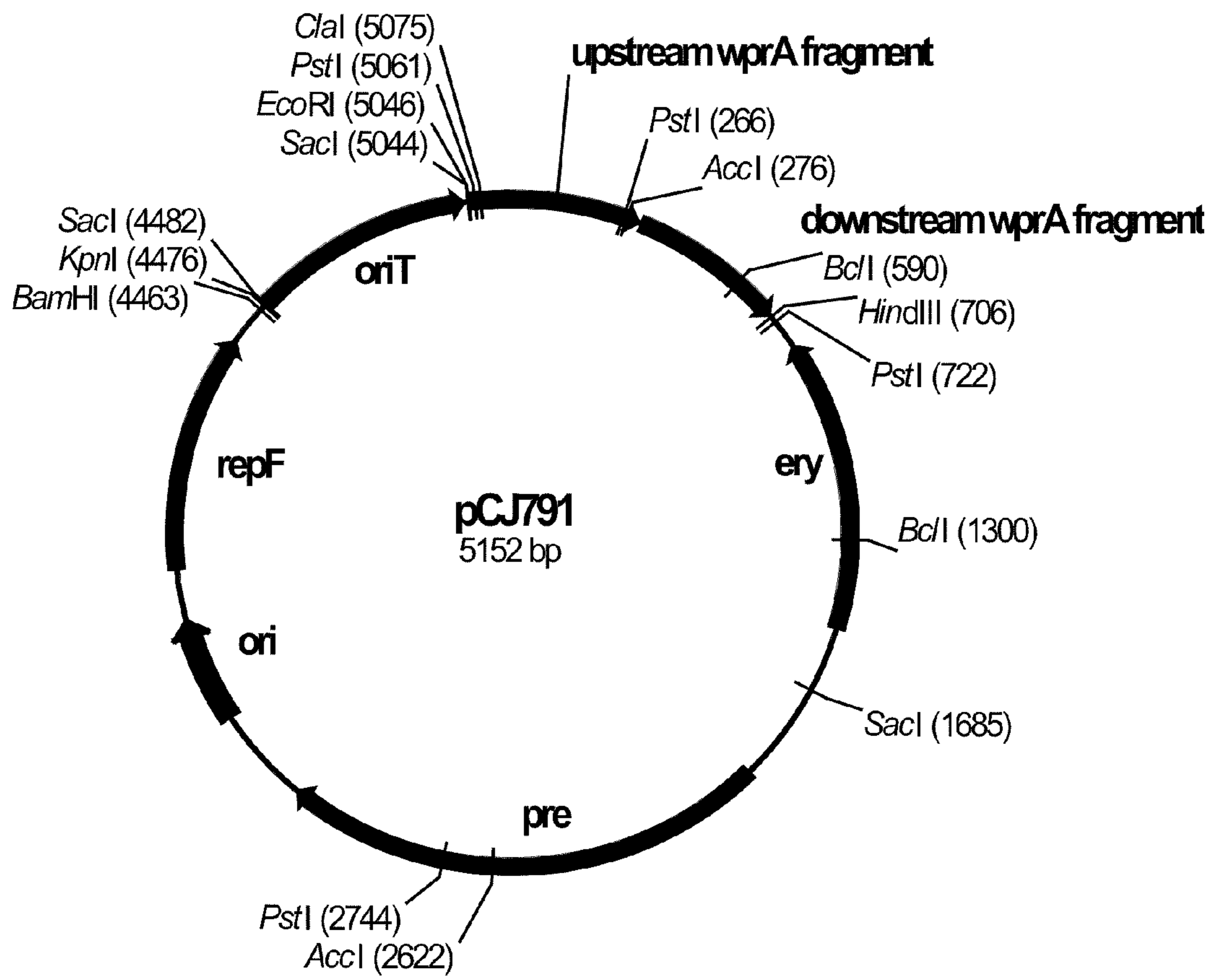


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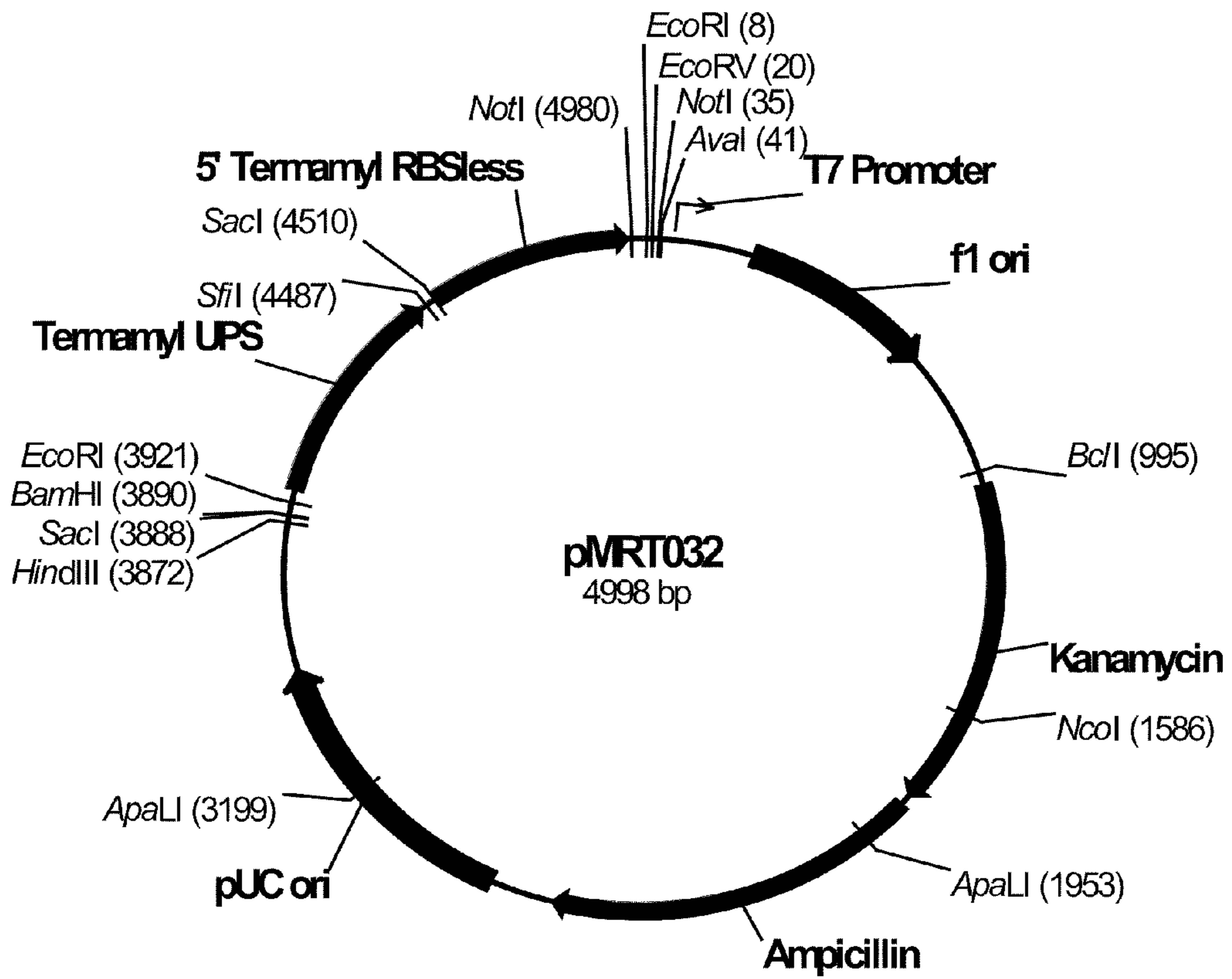


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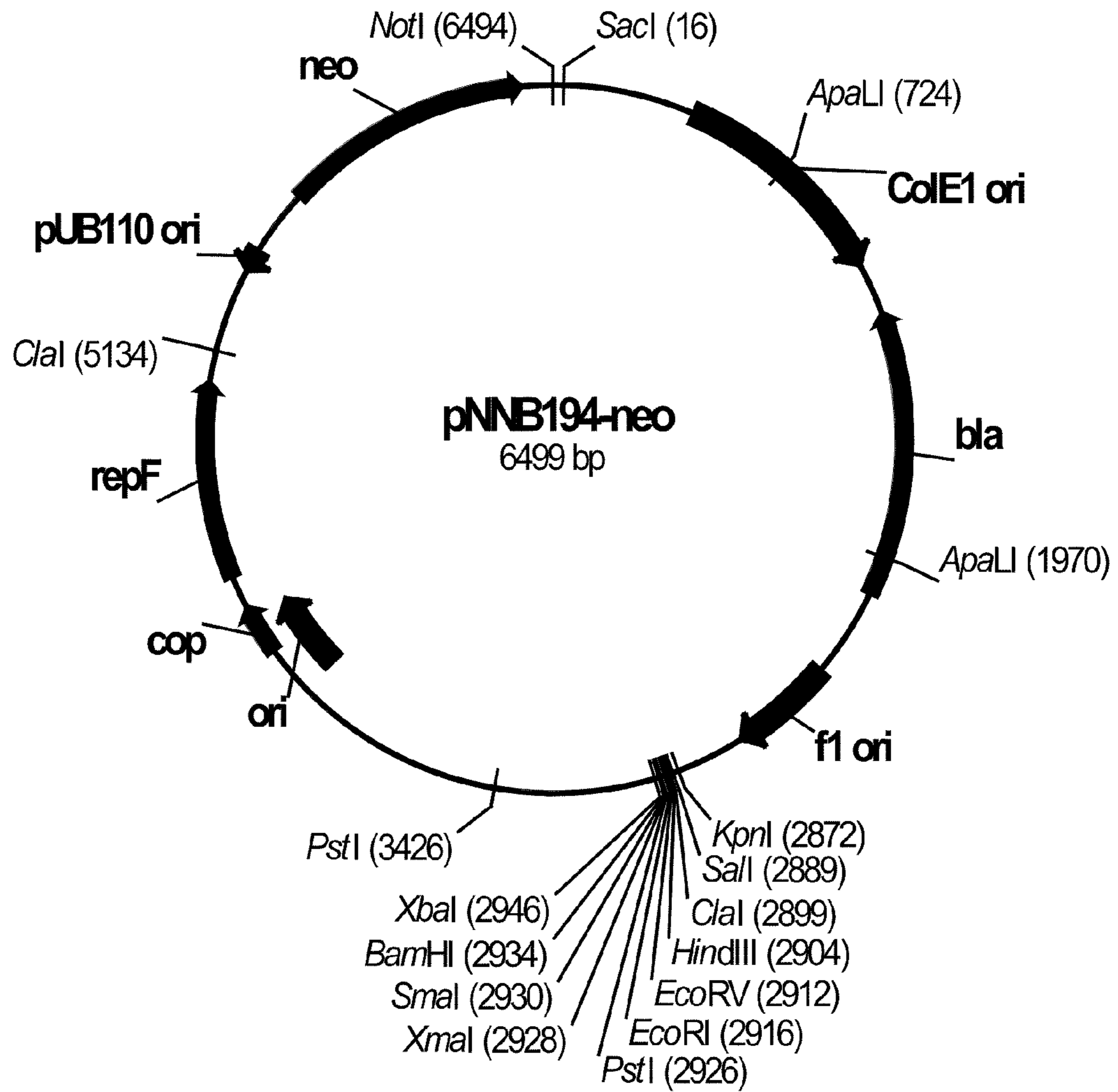


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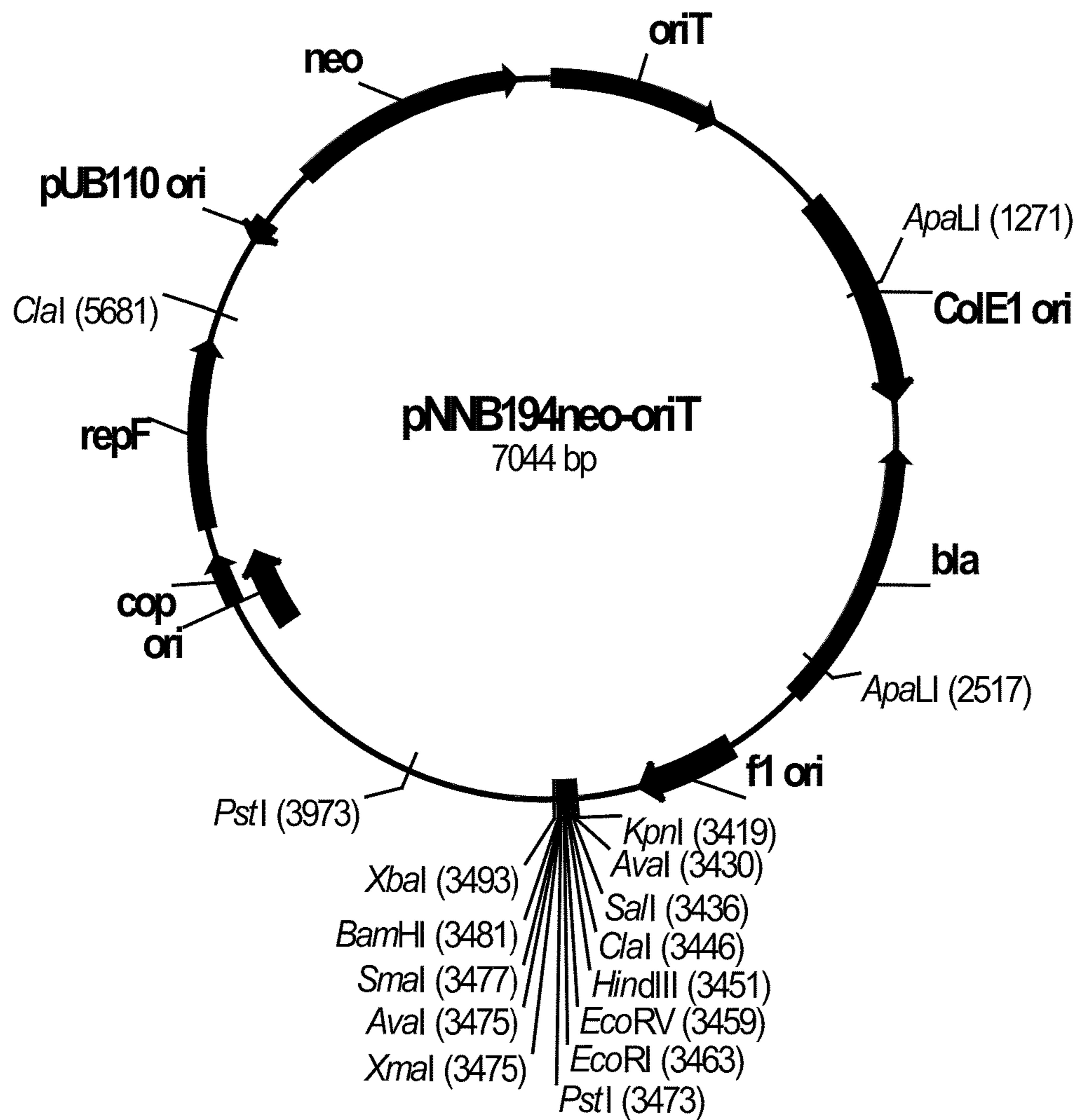


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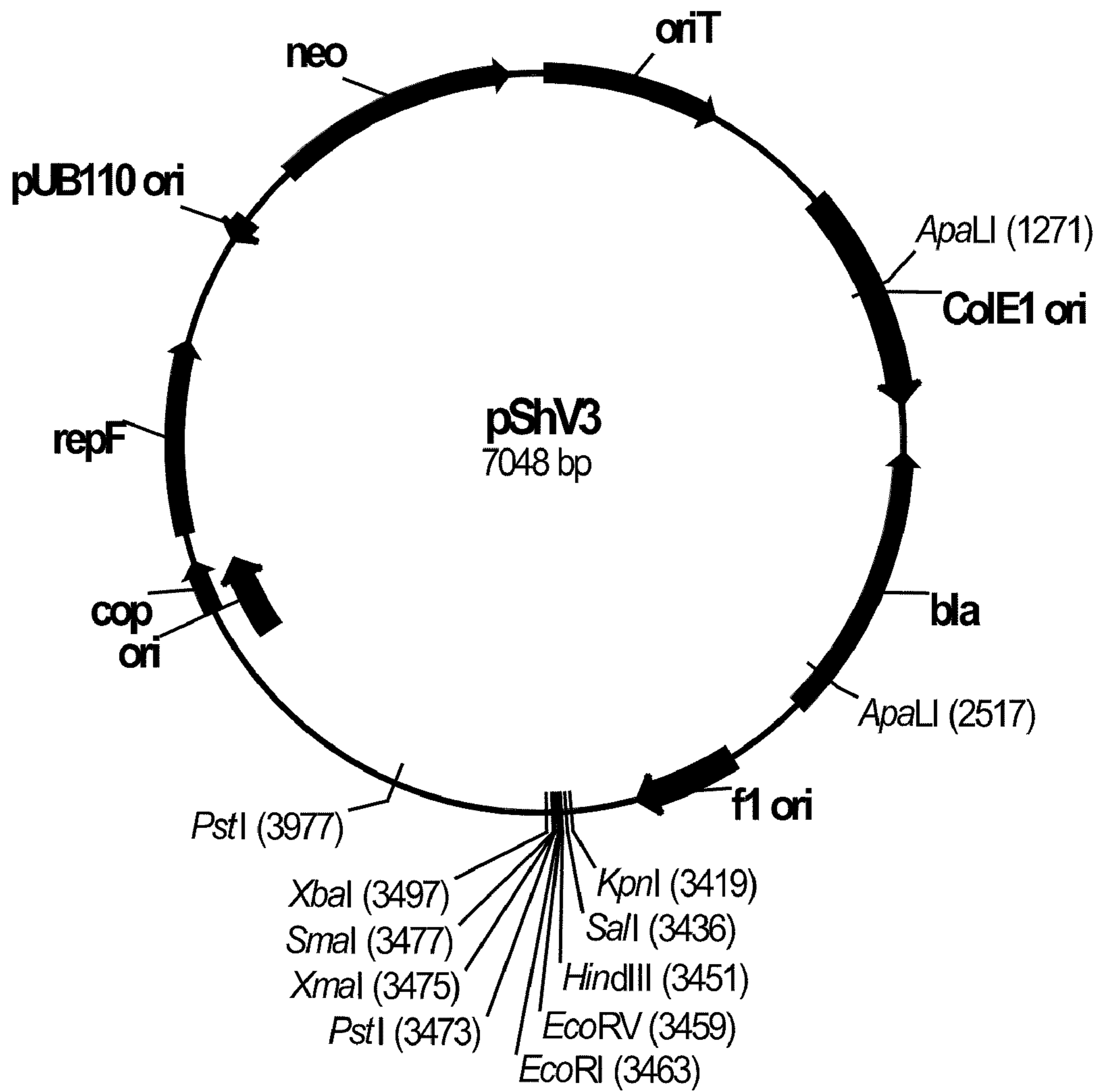


Fig. 25

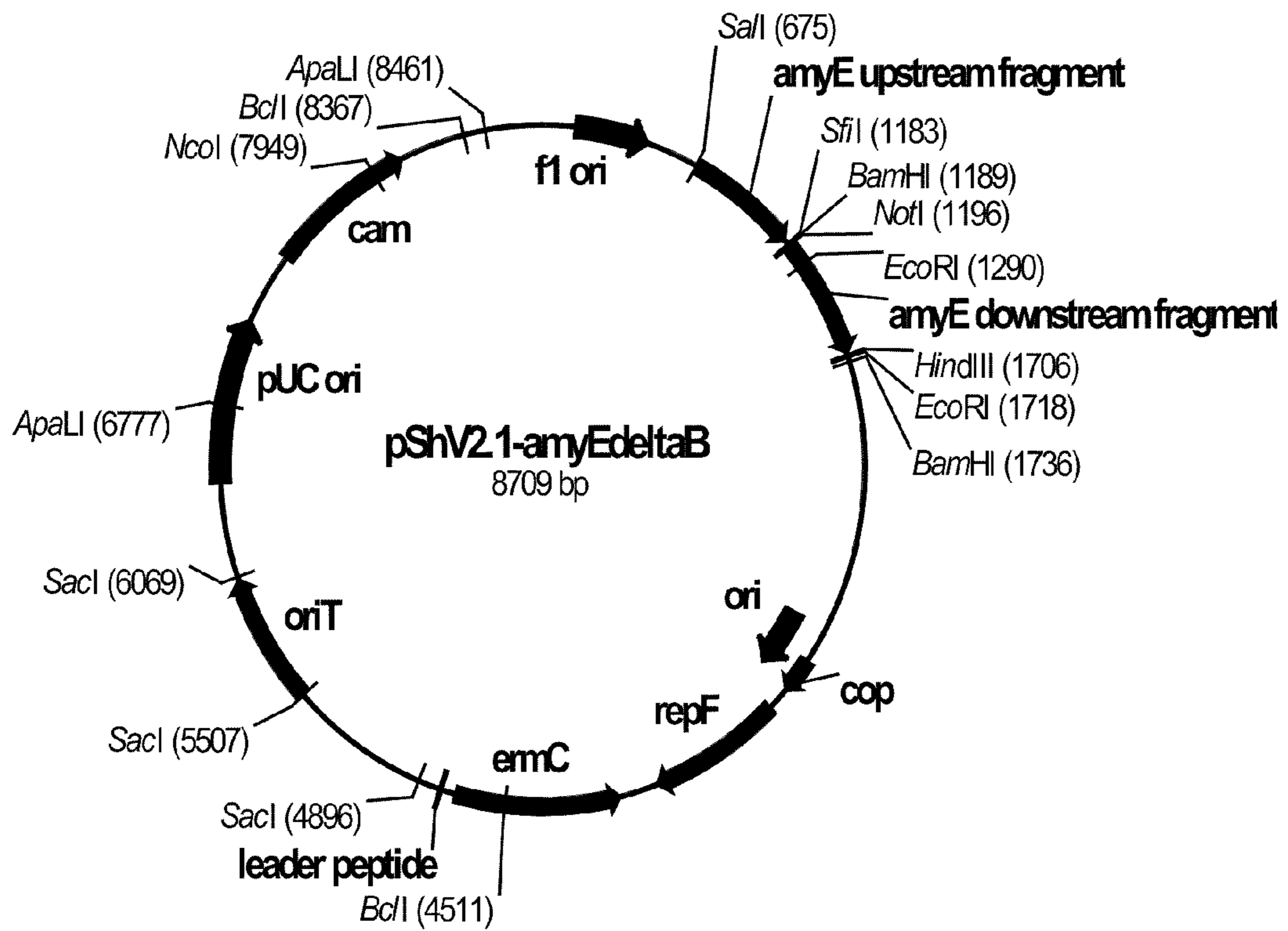


Fig. 26

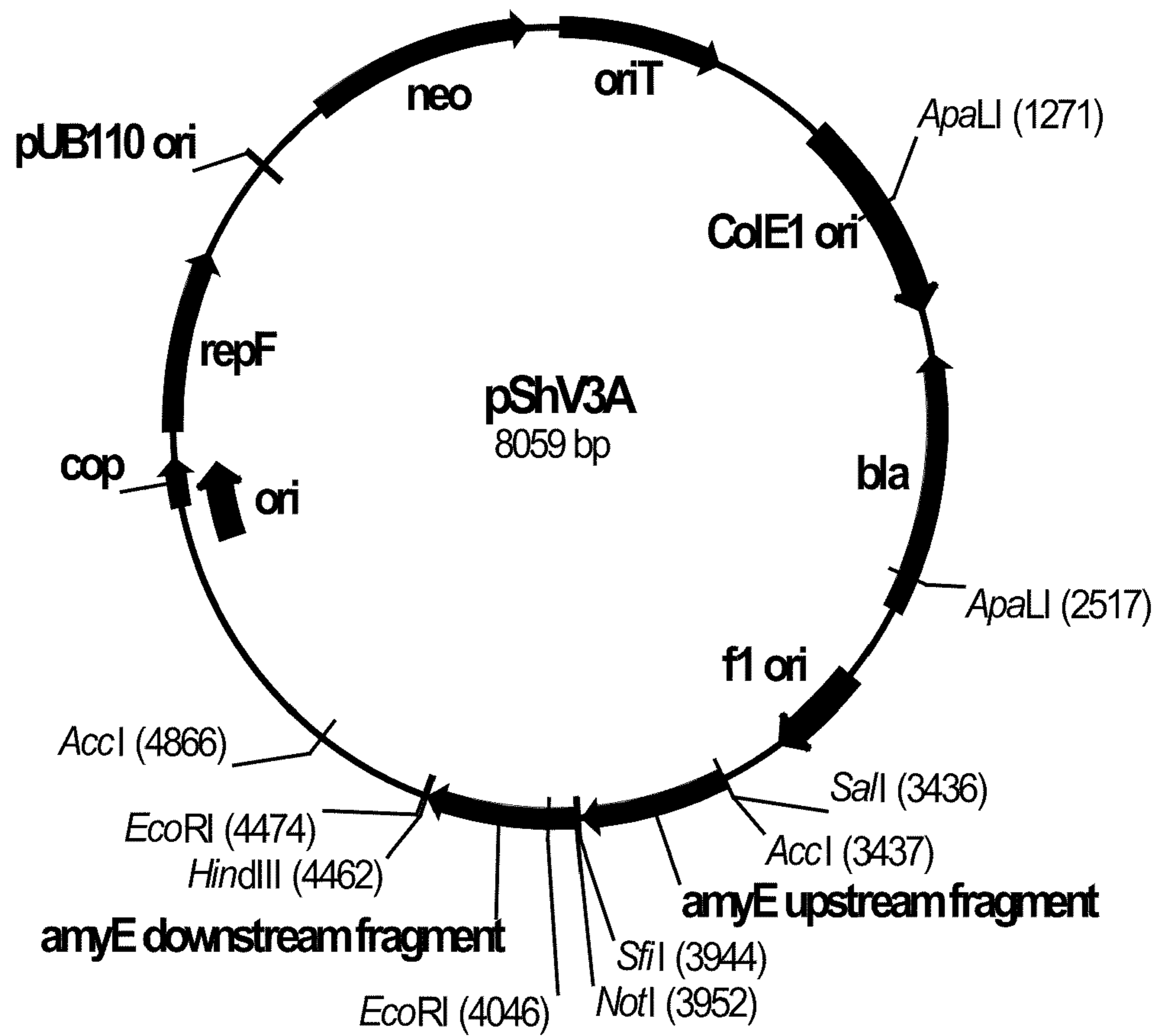


Fig. 27

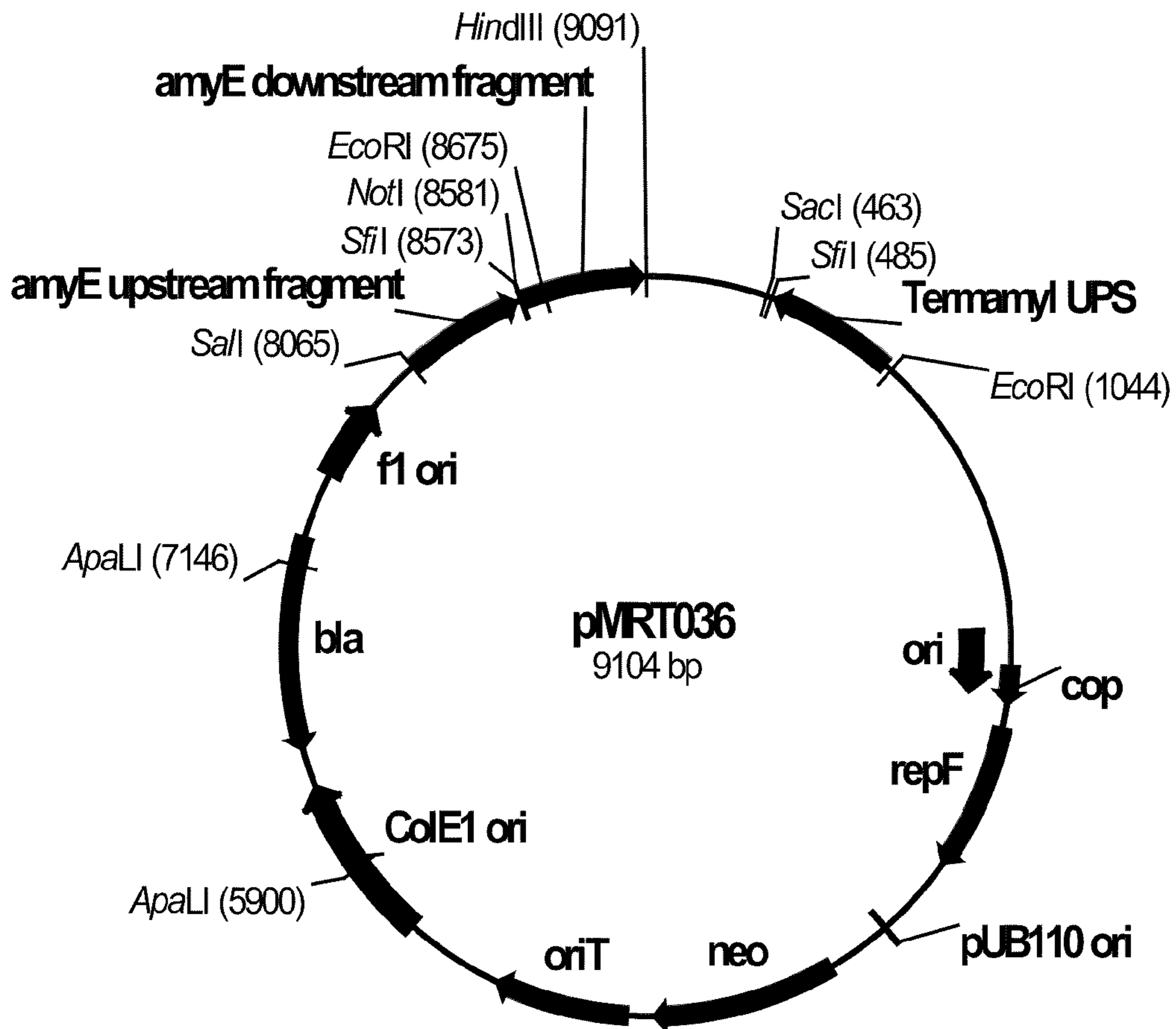


Fig. 28

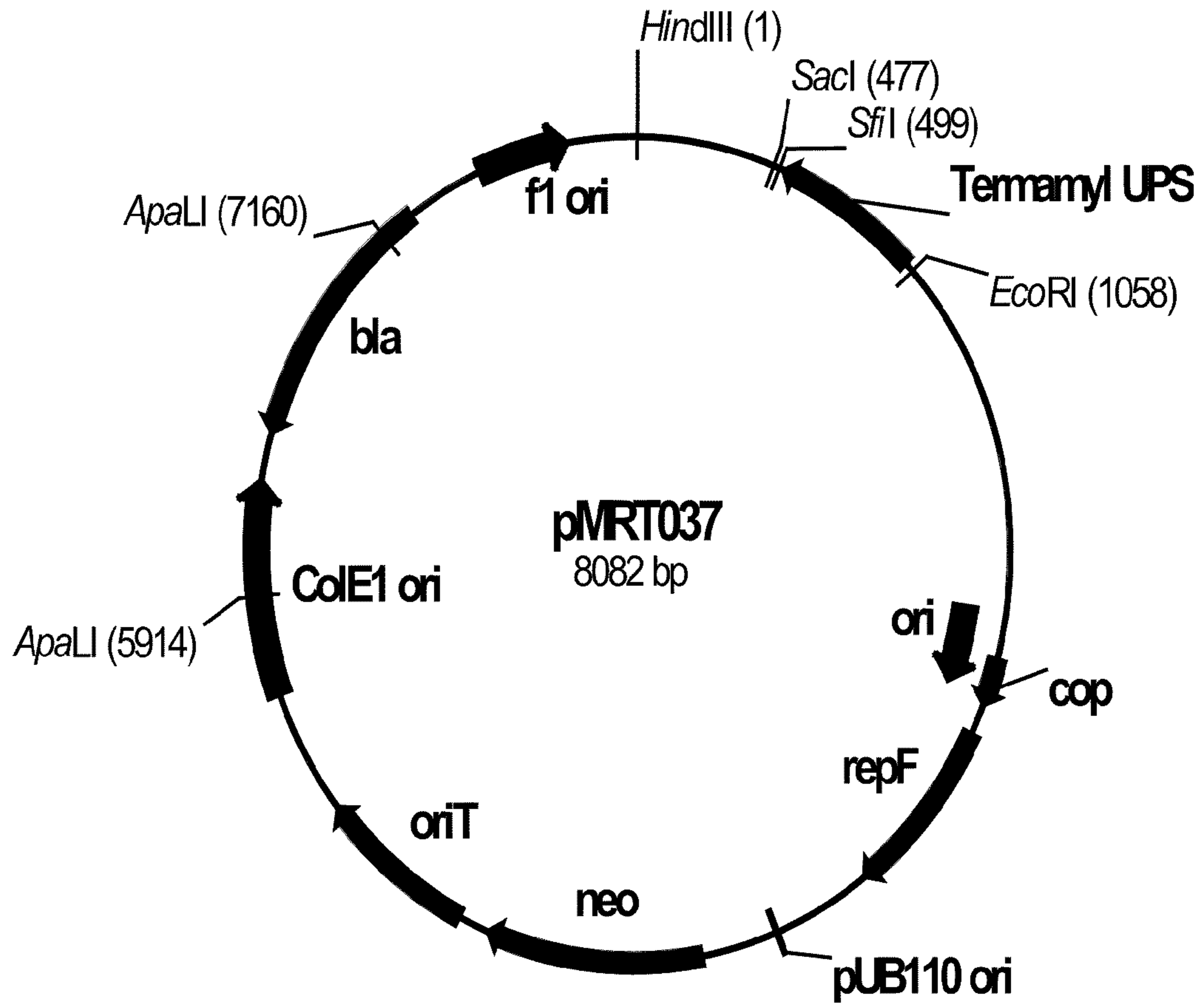


Fig. 29

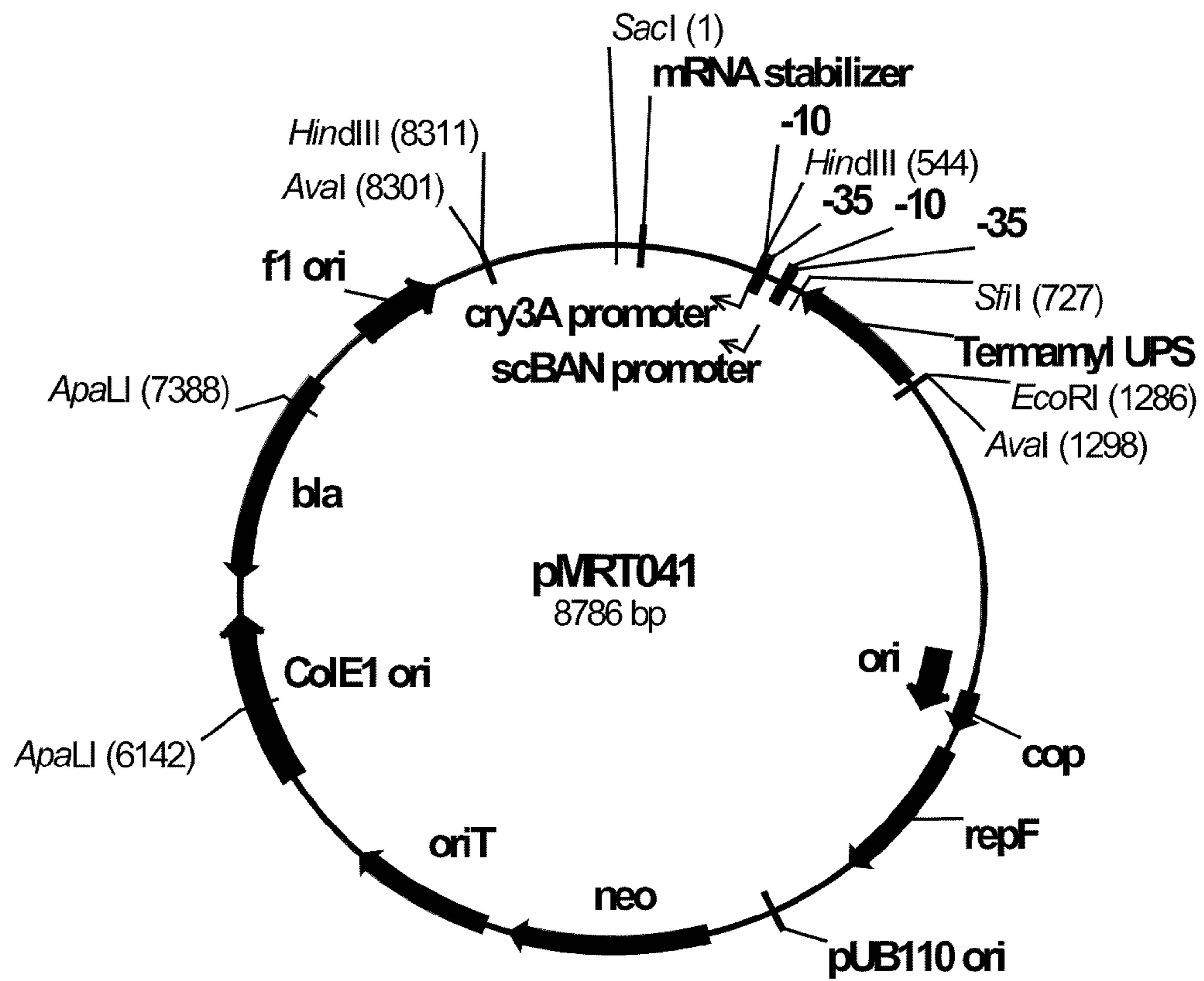


Fig. 30

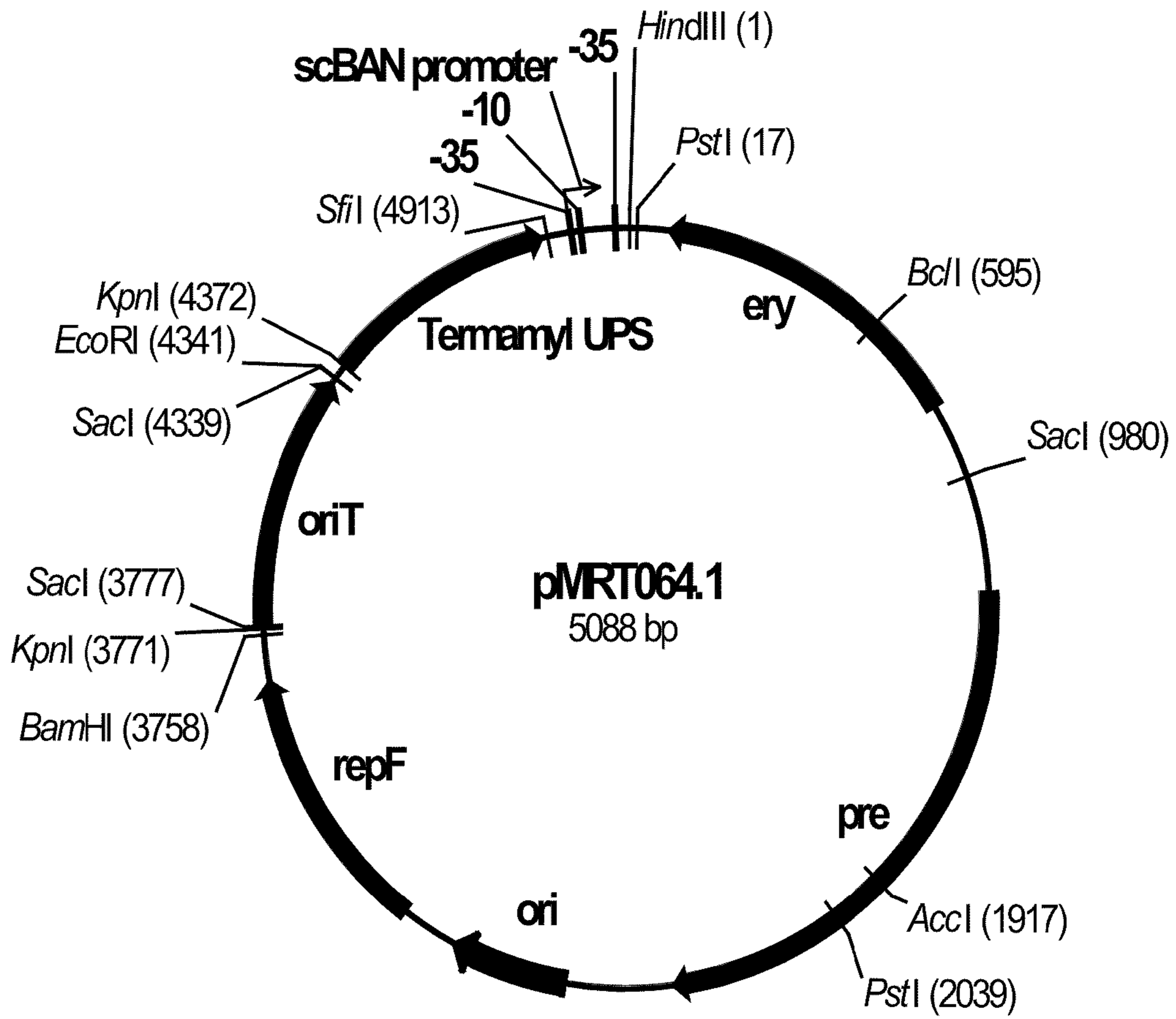


Fig. 31

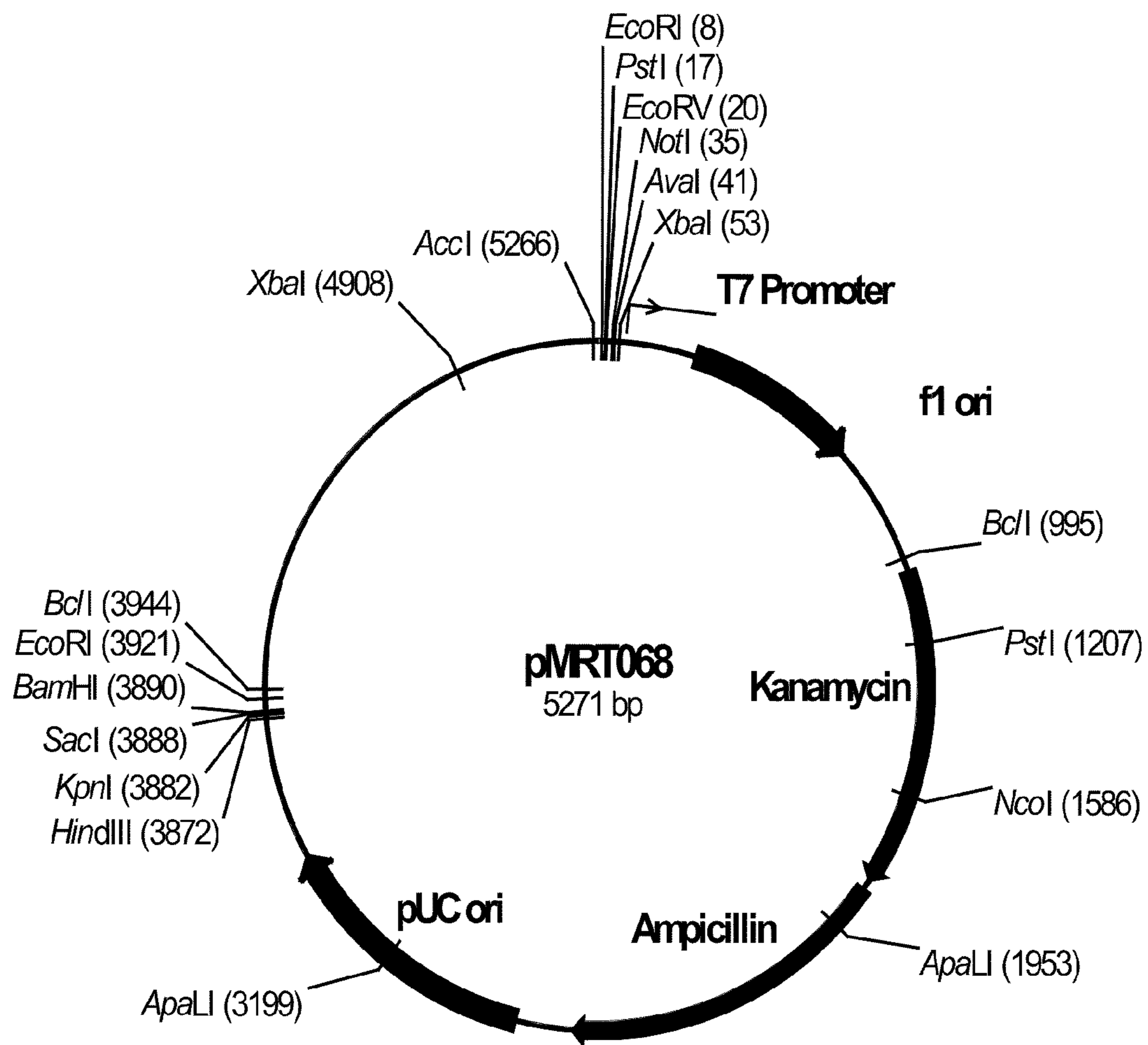


Fig. 32

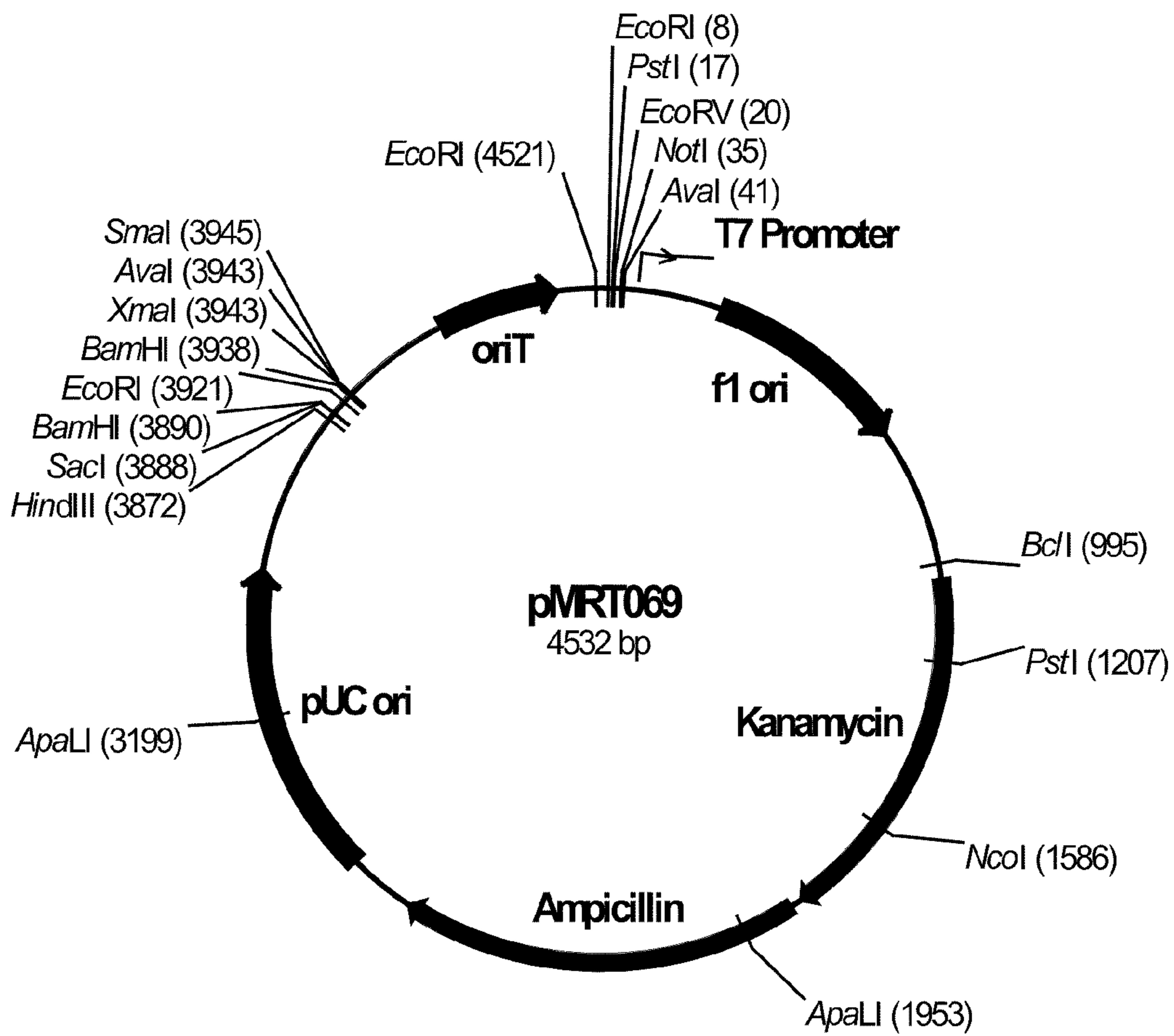


Fig. 33

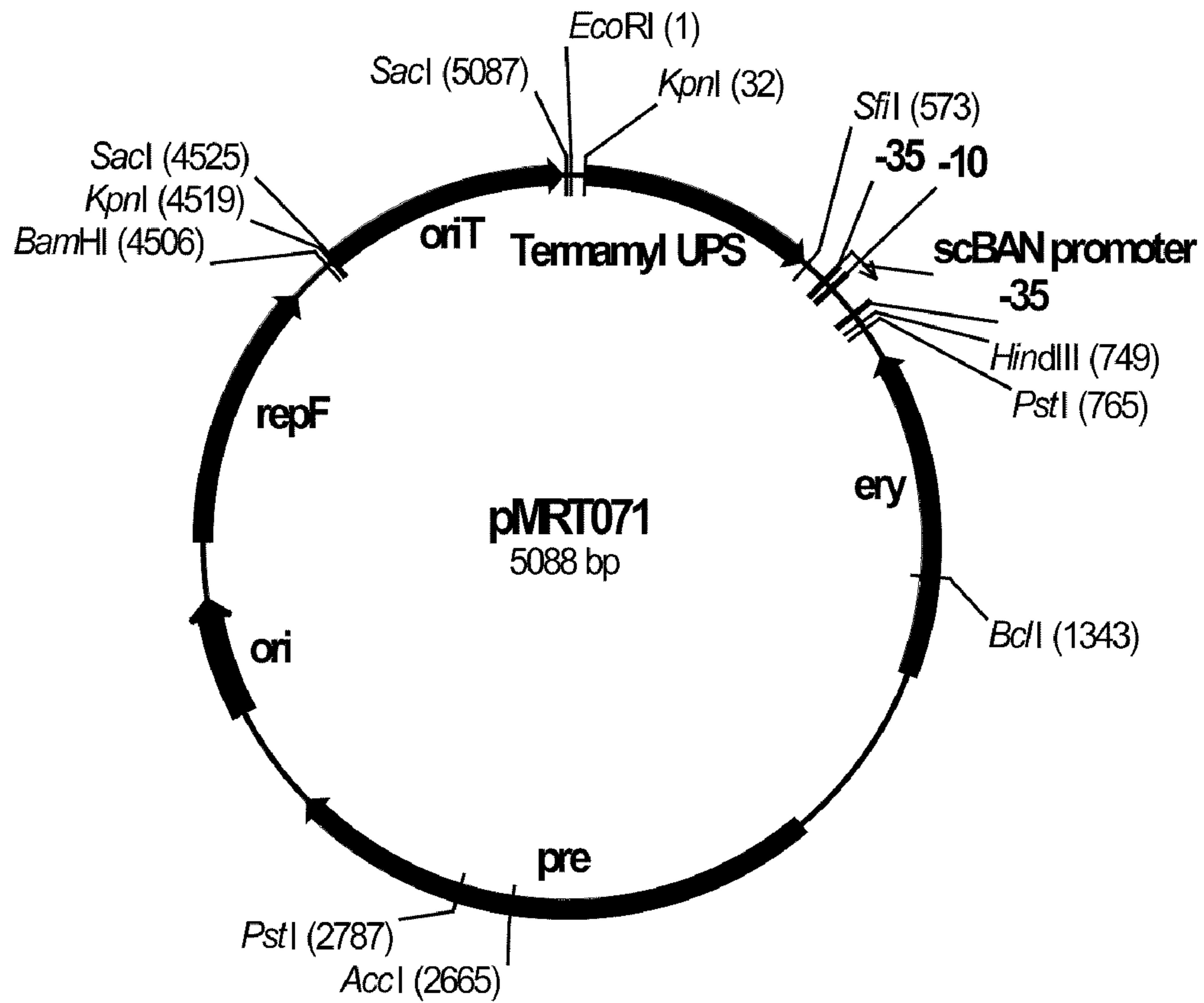


Fig. 34

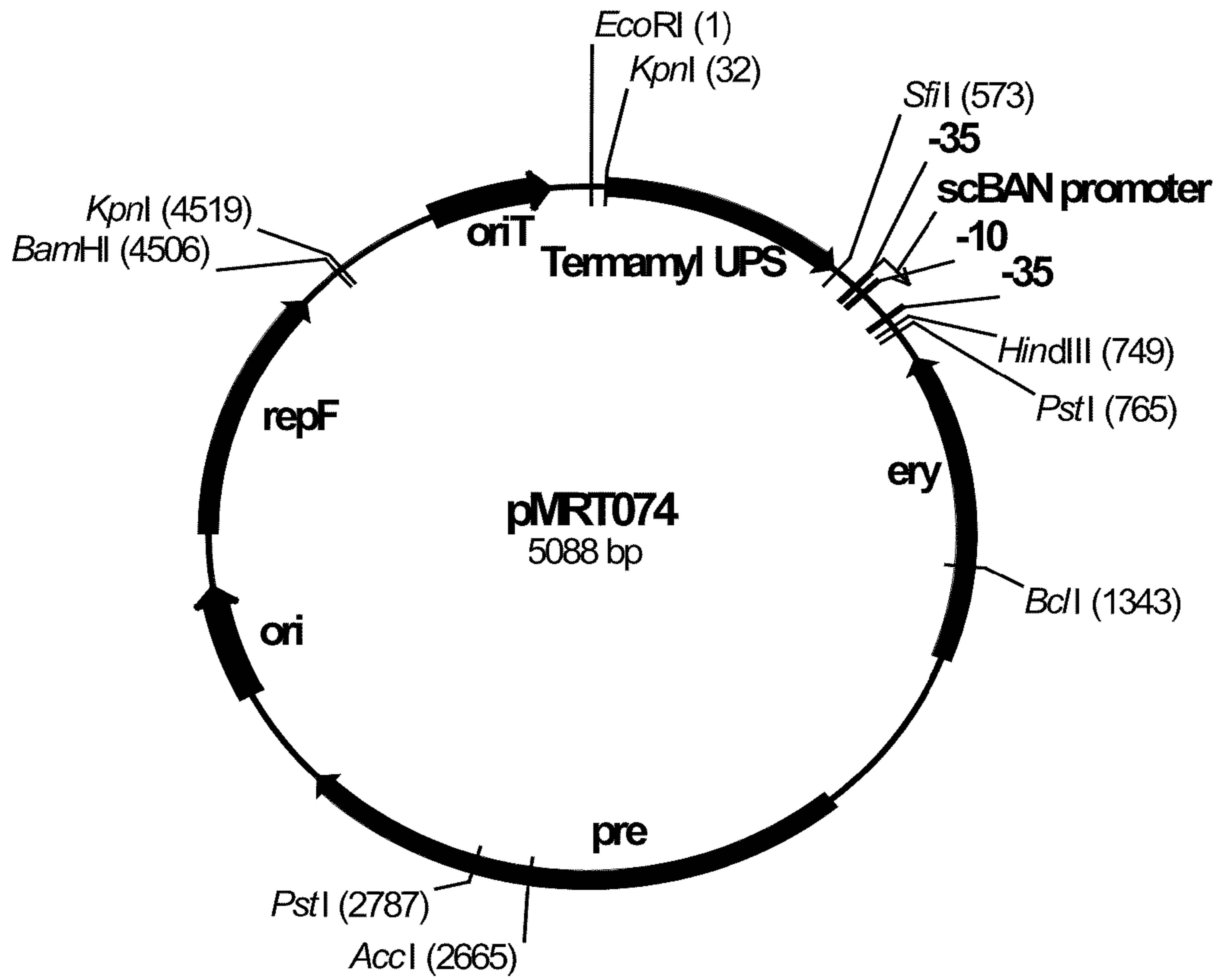


Fig. 35

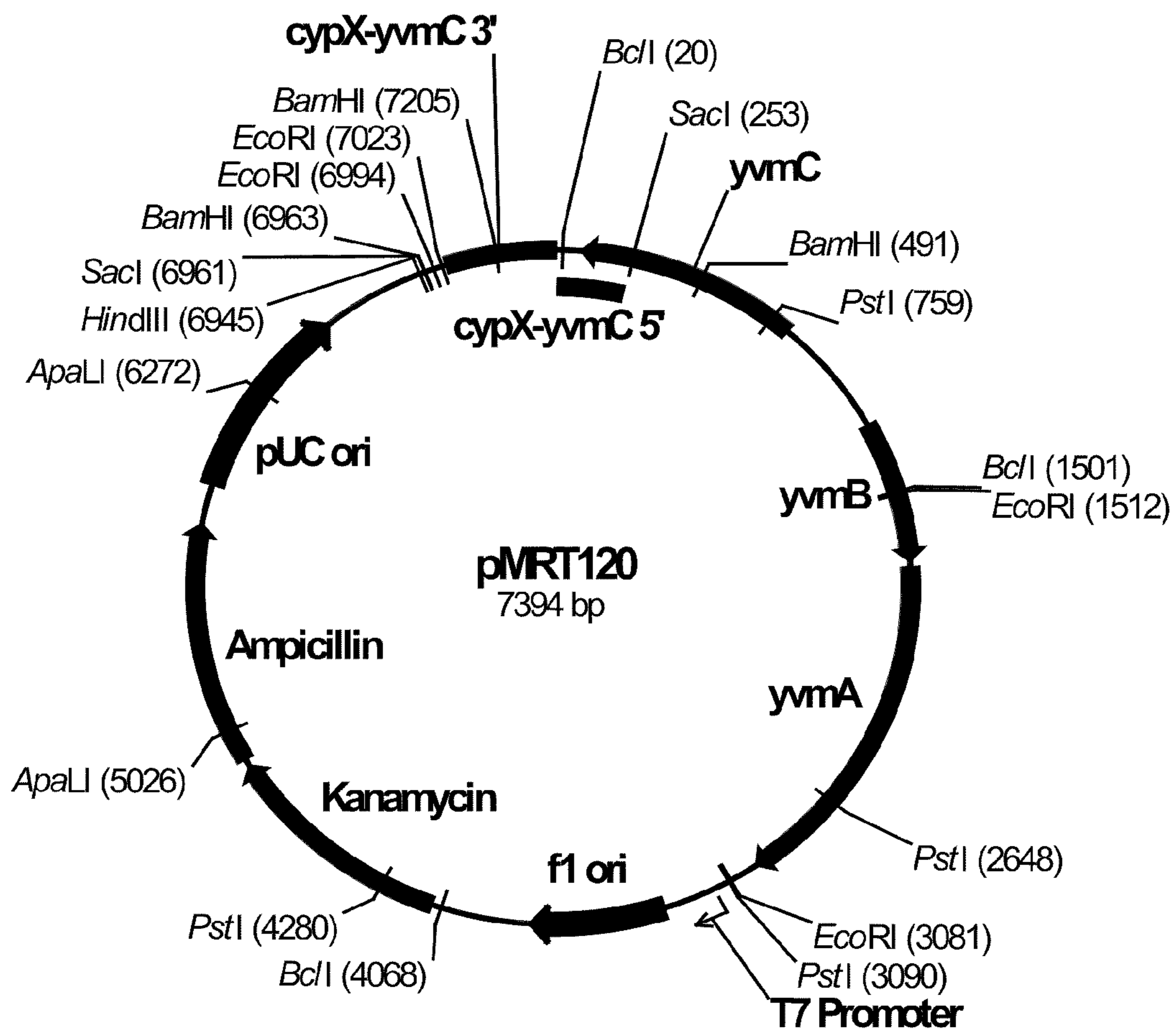


Fig. 36

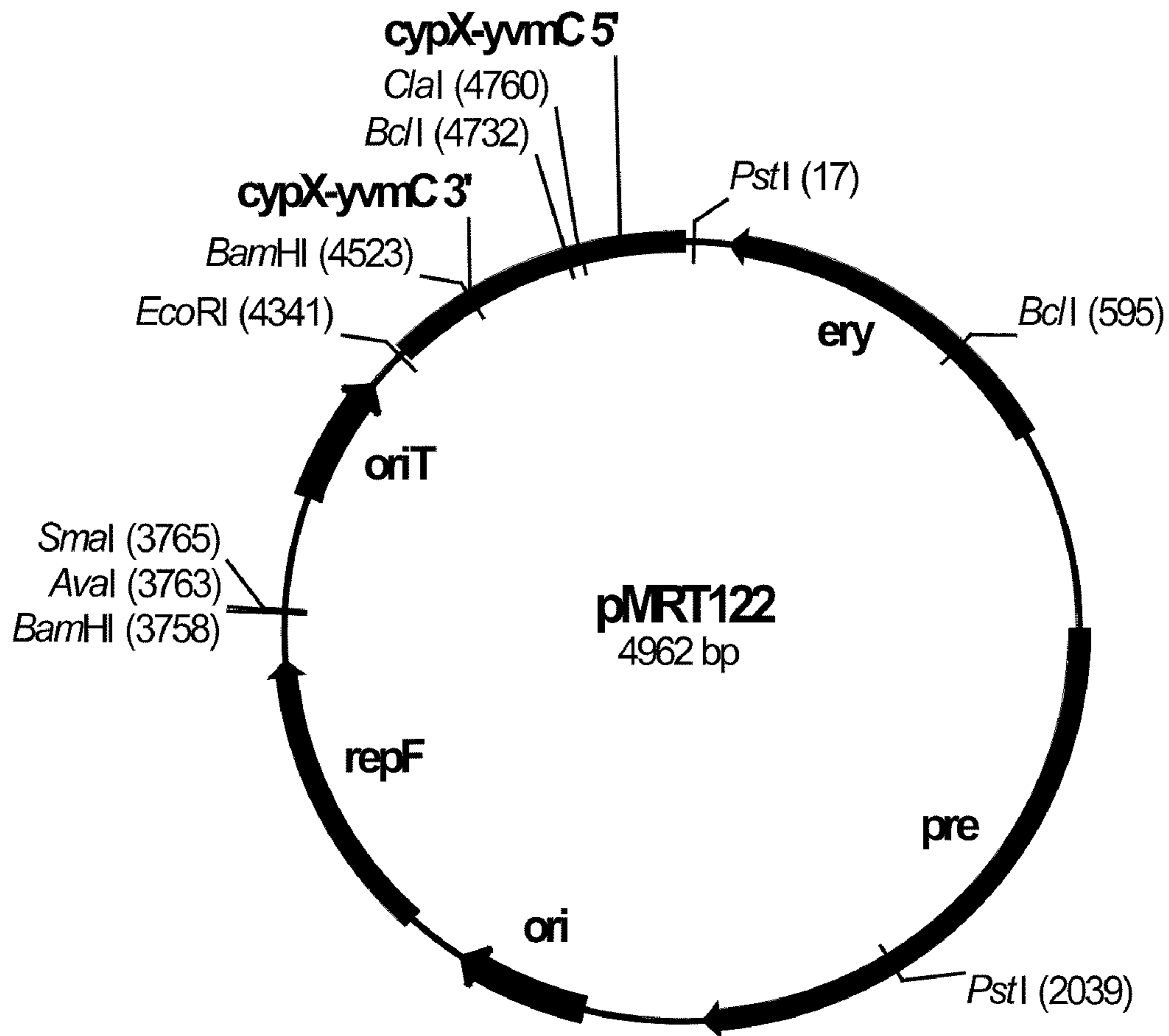


Fig. 37

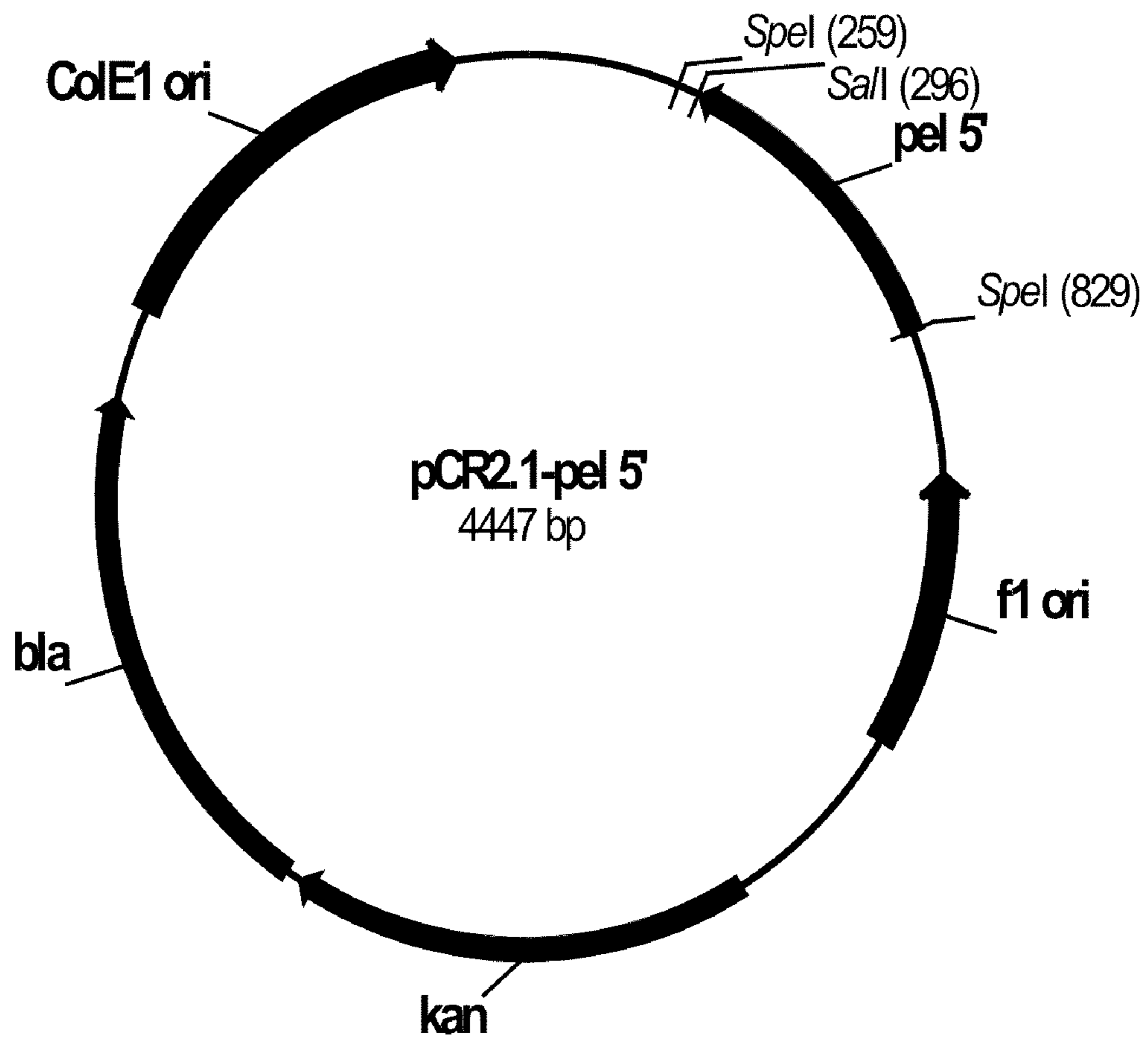


Fig. 38

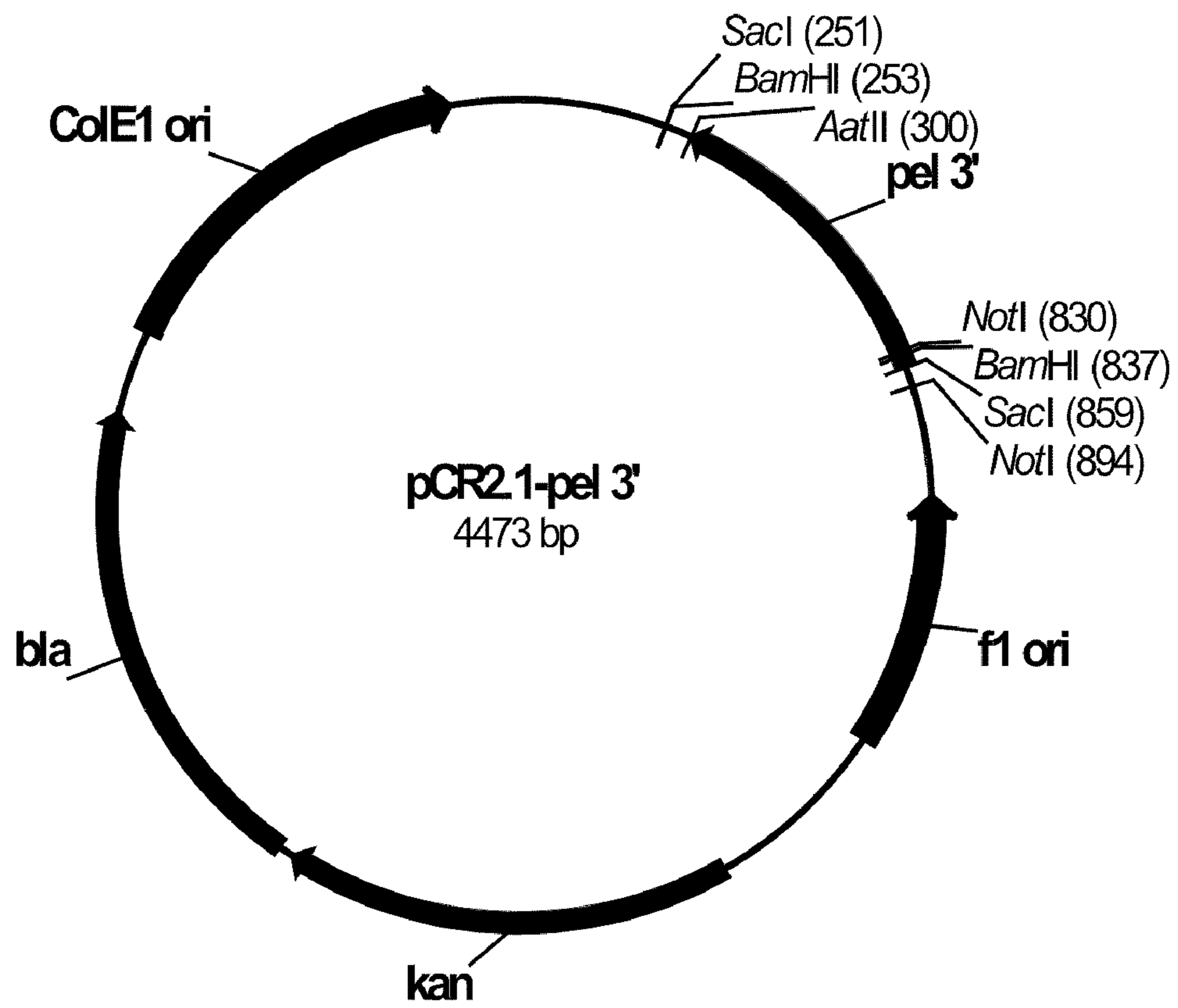


Fig. 39

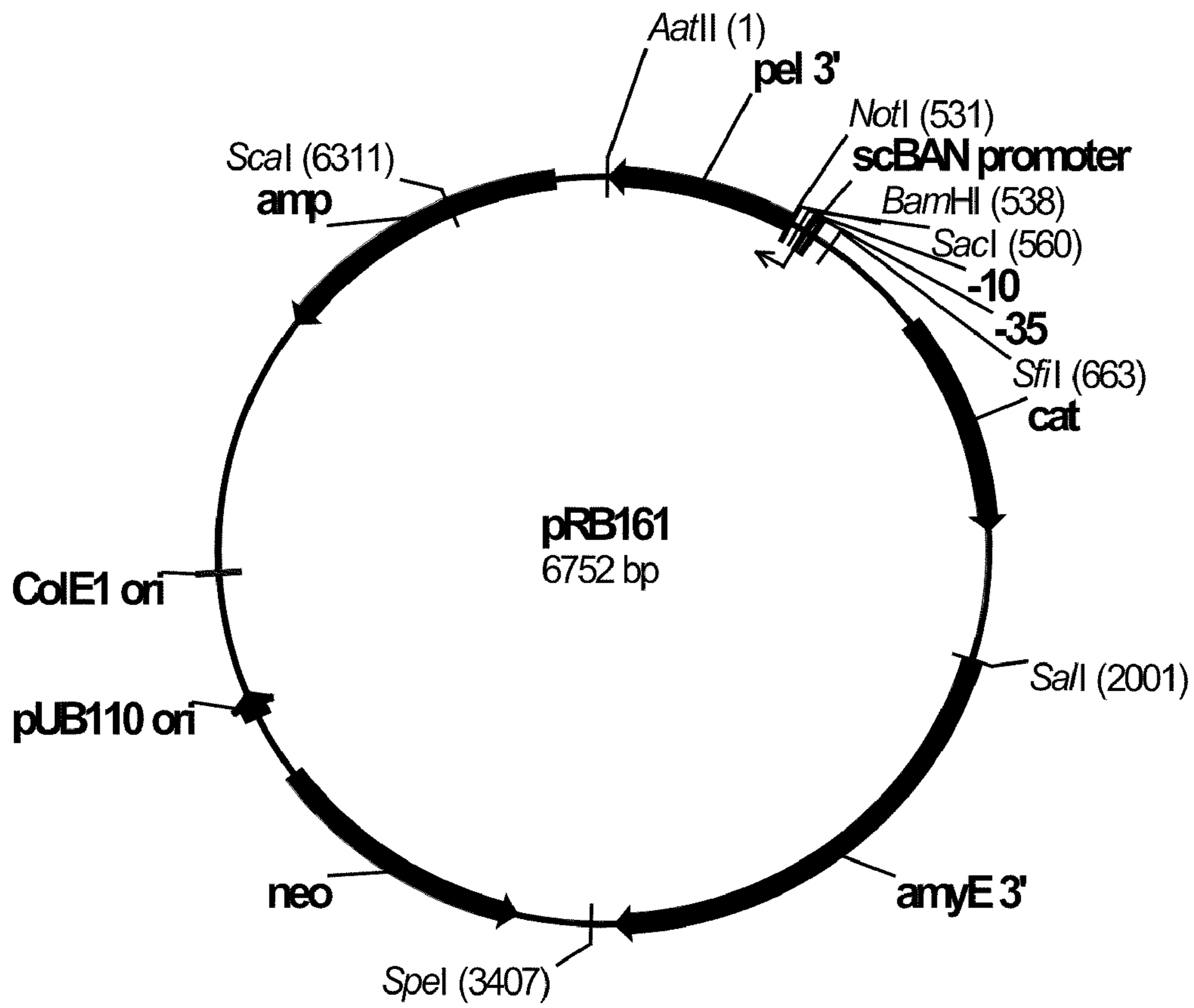


Fig. 40

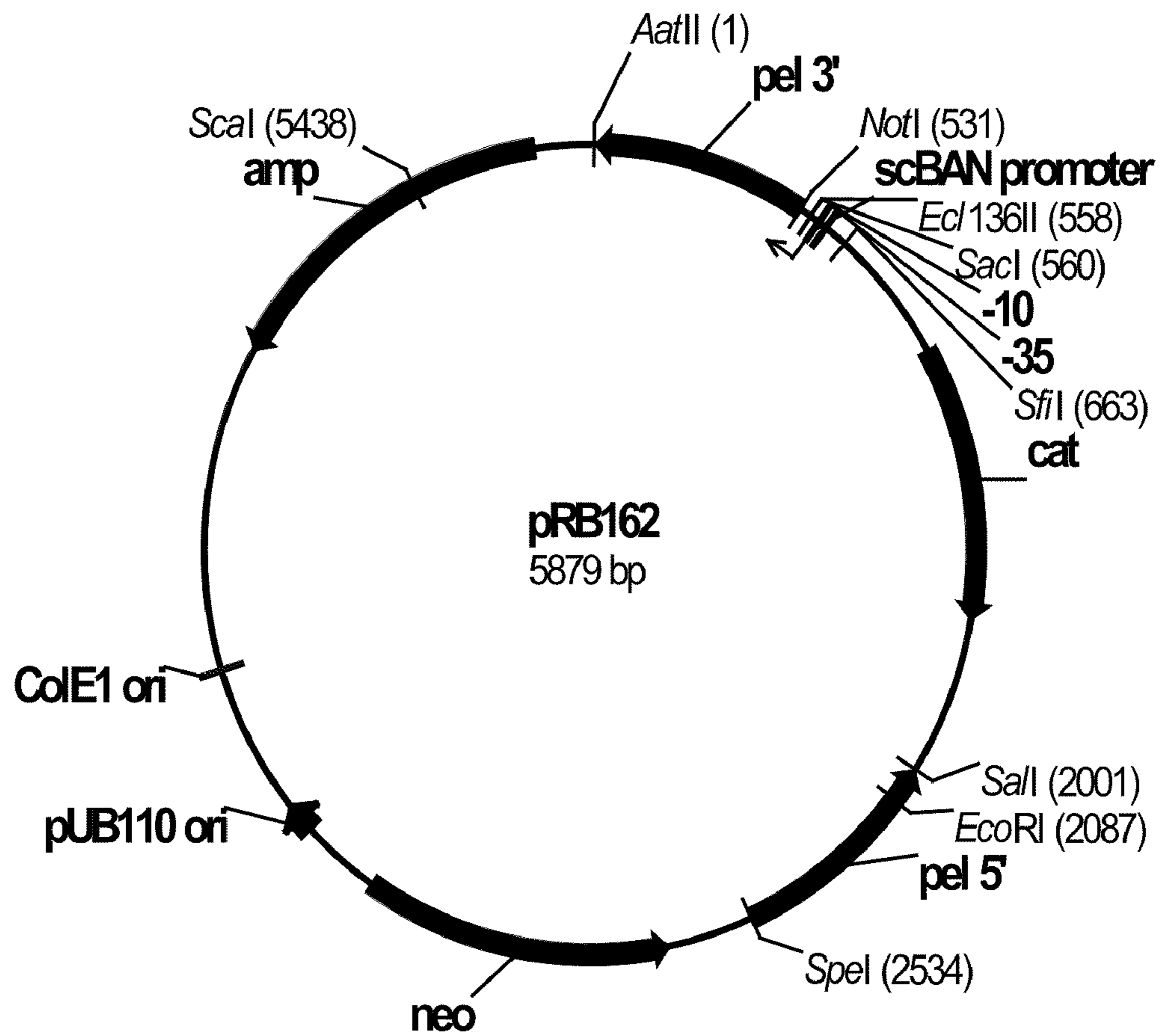


Fig. 41

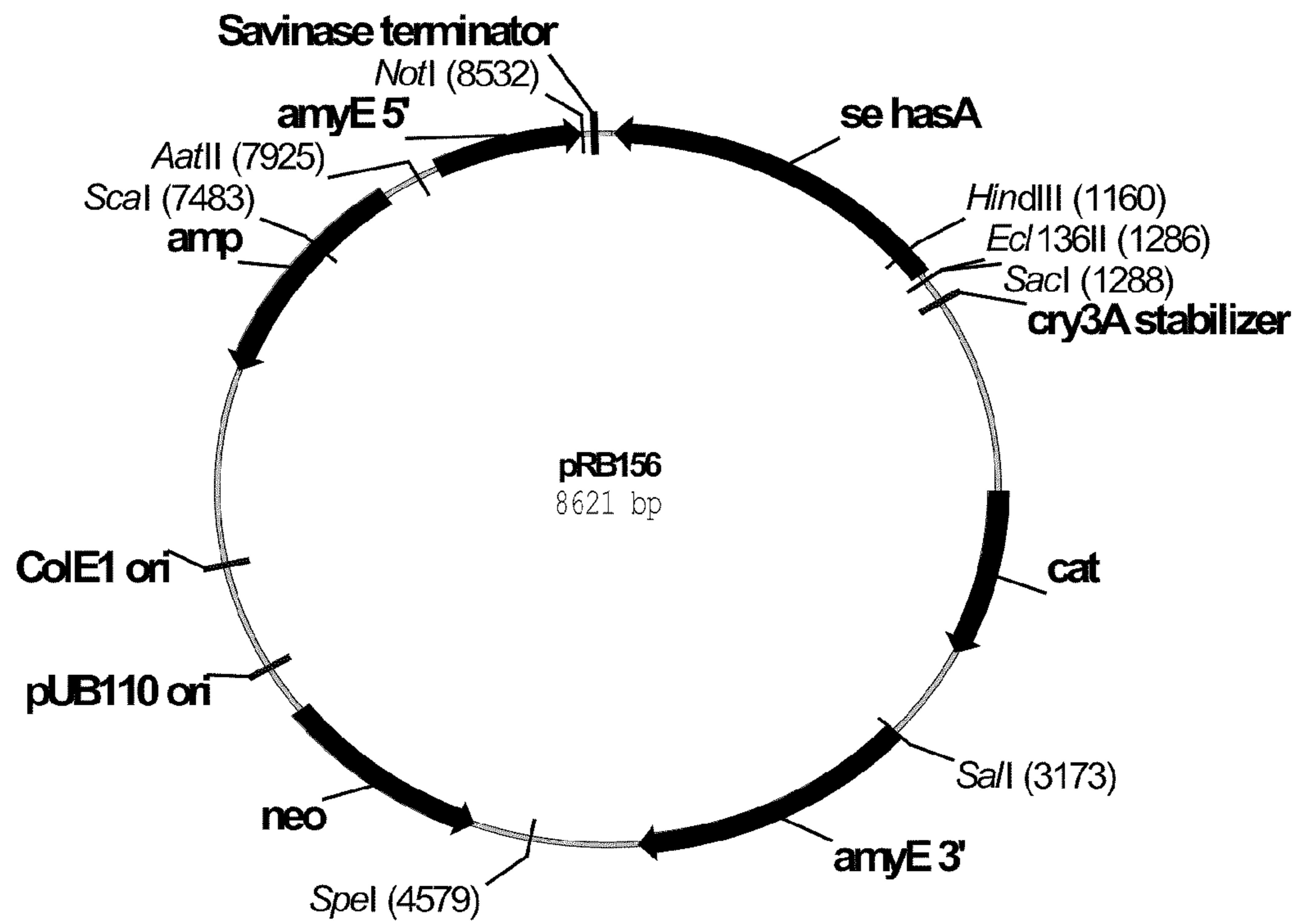


Fig. 42

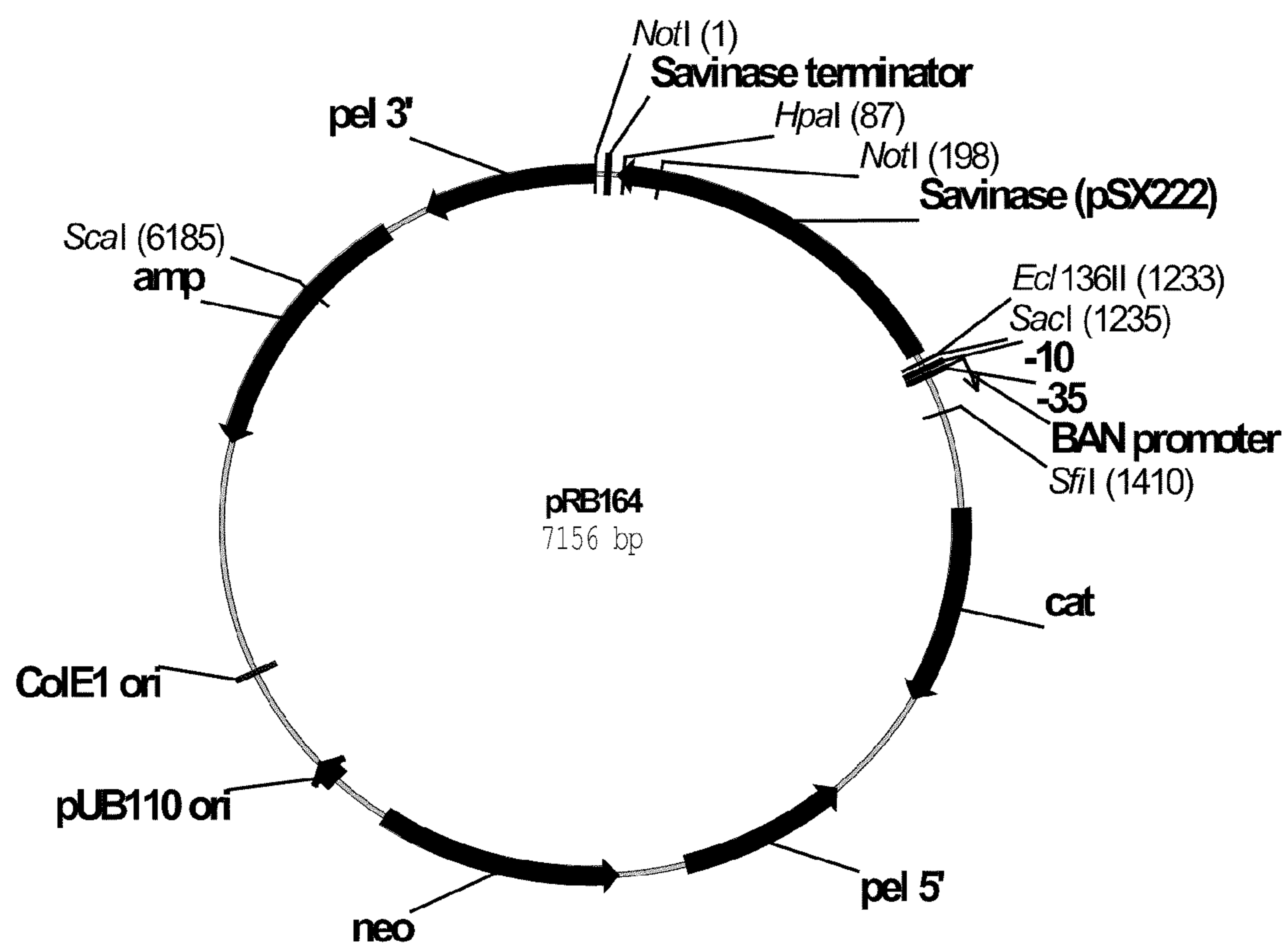


Fig. 43

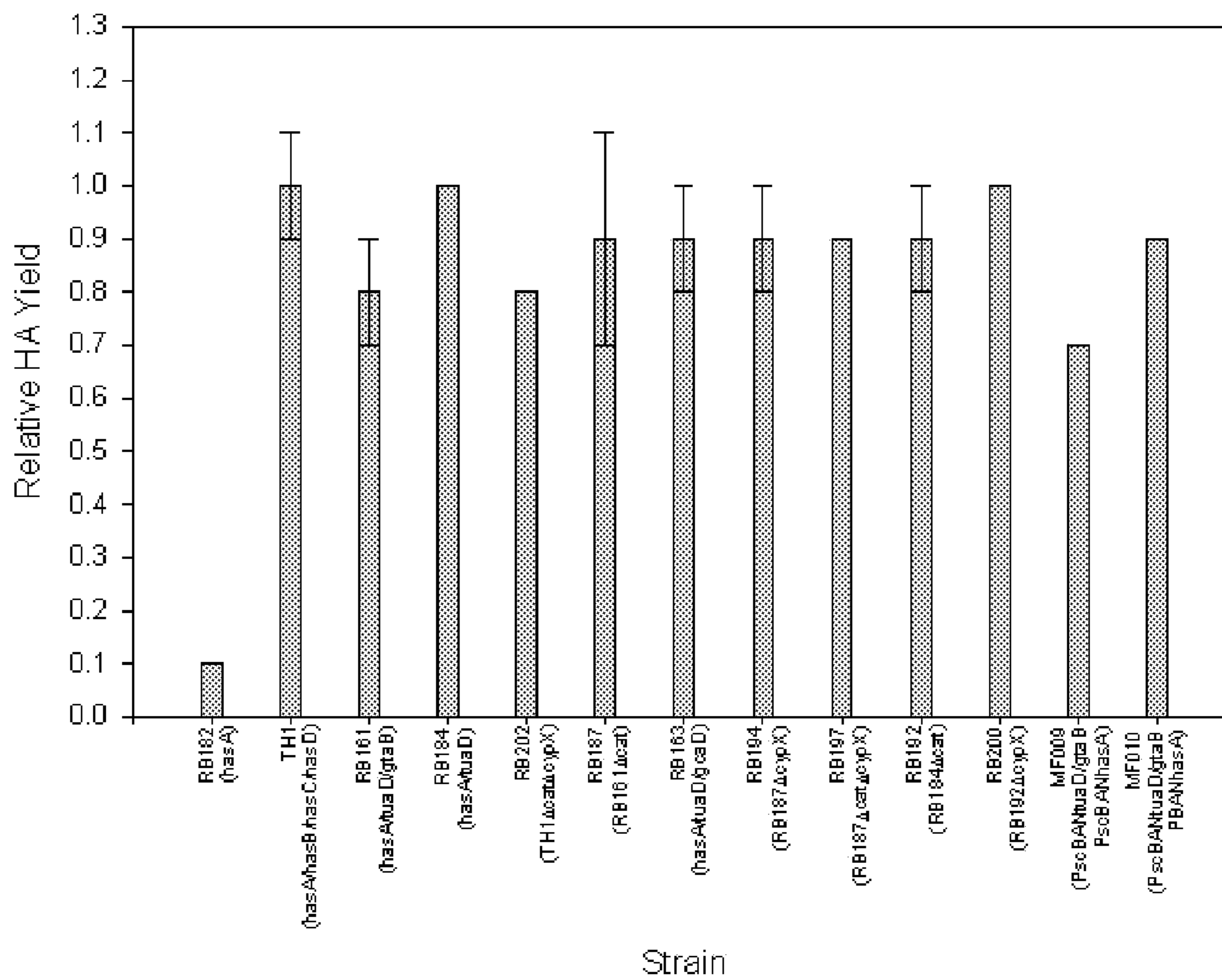


Fig. 44

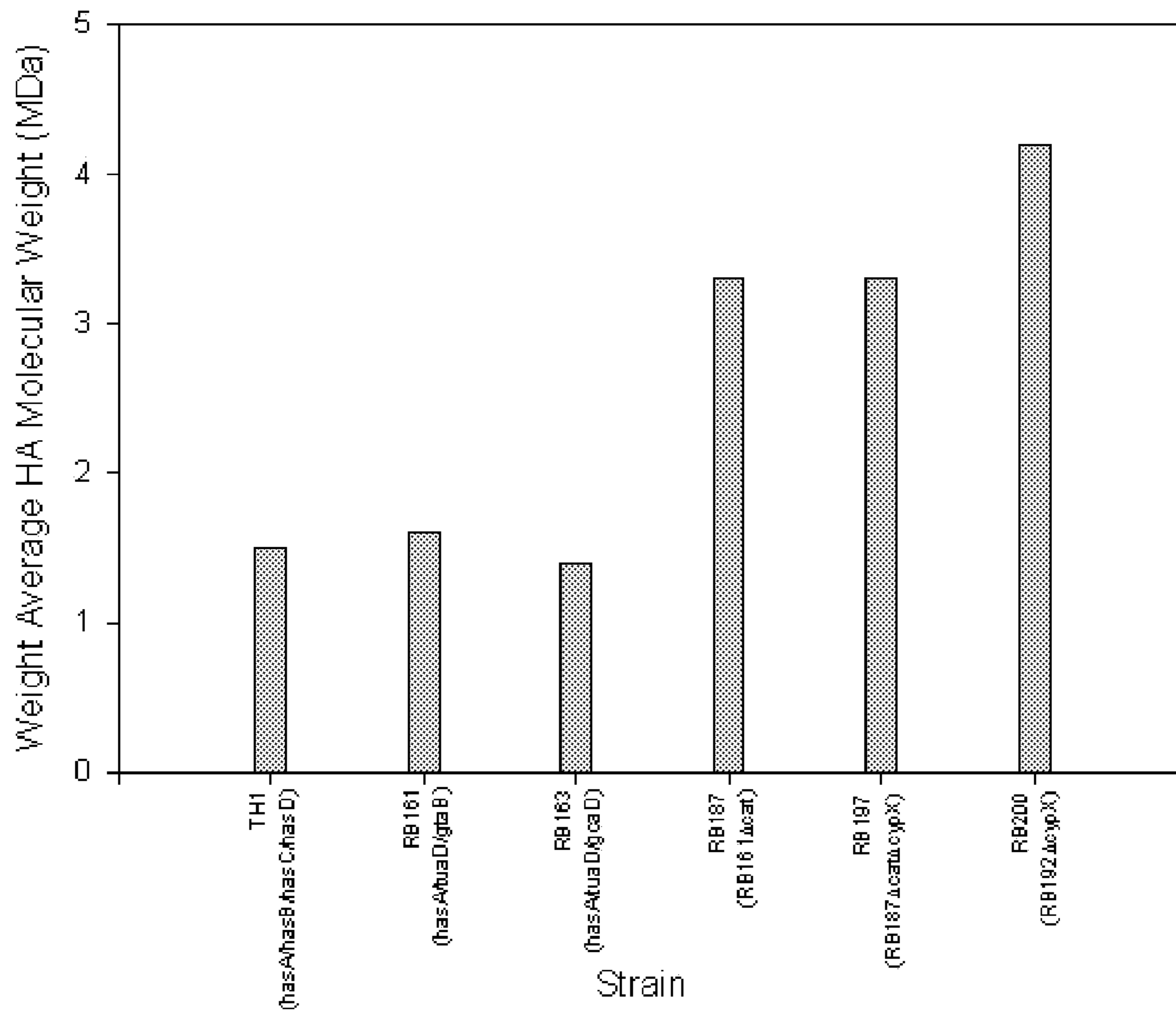


Fig. 45

METHODS FOR PRODUCING HYALURONAN IN A RECOMBINANT HOST CELL

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a divisional of U.S. application Ser. No. 12/891,548 filed Sep. 27, 2010, which is a divisional of U.S. application Ser. No. 10/326,185 filed Dec. 20, 2002, now U.S. Pat. No. 7,811,806, which claims priority from U.S. Provisional Application Ser. No. 60/342,644 filed Dec. 21, 2001, which applications are fully incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to methods for producing a hyaluronan in a recombinant host cell.

2. Description of the Related Art

The most abundant heteropolysaccharides of the body are the glycosaminoglycans. Glycosaminoglycans are unbranched carbohydrate polymers, consisting of repeating disaccharide units (only keratan sulphate is branched in the core region of the carbohydrate). The disaccharide units generally comprise, as a first saccharide unit, one of two modified sugars—N-acetylgalactosamine (GalNAc) or N-acetylglucosamine (GlcNAc). The second unit is usually an uronic acid, such as glucuronic acid (GlcUA) or iduronate.

Glycosaminoglycans are negatively charged molecules, and have an extended conformation that imparts high viscosity when in solution. Glycosaminoglycans are located primarily on the surface of cells or in the extracellular matrix. Glycosaminoglycans also have low compressibility in solution and, as a result, are ideal as a physiological lubricating fluid, e.g., joints. The rigidity of glycosaminoglycans provides structural integrity to cells and provides passageways between cells, allowing for cell migration. The glycosaminoglycans of highest physiological importance are hyaluronan, chondroitin sulfate, heparin, heparan sulfate, dermatan sulfate, and keratan sulfate. Most glycosaminoglycans bind covalently to a proteoglycan core protein through specific oligosaccharide structures. Hyaluronan forms large aggregates with certain proteoglycans, but is an exception as free carbohydrate chains form non-covalent complexes with proteoglycans.

Numerous roles of hyaluronan in the body have been identified (see, Laurent T. C. and Fraser J. R. E., 1992, *FASEB J.* 6: 2397-2404; and Toole B. P., 1991, "Proteoglycans and hyaluronan in morphogenesis and differentiation." In: *Cell Biology of the Extracellular Matrix*, pp. 305-341, Hay E. D., ed., Plenum, N.Y.). Hyaluronan is present in hyaline cartilage, synovial joint fluid, and skin tissue, both dermis and epidermis. Hyaluronan is also suspected of having a role in numerous physiological functions, such as adhesion, development, cell motility, cancer, angiogenesis, and wound healing. Due to the unique physical and biological properties of hyaluronan, it is employed in eye and joint surgery and is being evaluated in other medical procedures. Products of hyaluronan have also been developed for use in orthopaedics, rheumatology, and dermatology.

Rooster combs are a significant commercial source for hyaluronan. Microorganisms are an alternative source. U.S. Pat. No. 4,801,539 discloses a fermentation method for preparing hyaluronic acid involving a strain of *Streptococcus zooepidemicus* with reported yields of about 3.6 g of hyaluronic acid per liter. European Patent No. EP0694616 discloses fermentation processes using an improved strain of

Streptococcus zooepidemicus with reported yields of about 3.5 g of hyaluronic acid per liter.

The microorganisms used for production of hyaluronic acid by fermentation are strains of pathogenic bacteria, foremost among them being several *Streptococcus* spp. The group A and group C streptococci surround themselves with a nonantigenic capsule composed of hyaluronan, which is identical in composition to that found in connective tissue and joints. *Pasteurella multocida*, another pathogenic encapsulating bacteria, also surrounds its cells with hyaluronan.

Hyaluronan synthases have been described from vertebrates, bacterial pathogens, and algal viruses (DeAngelis, P. L., 1999, *Cell. Mol. Life. Sci.* 56: 670-682). WO 99/23227 discloses a Group I hyaluronate synthase from *Streptococcus equisimilis*. WO 99/51265 and WO 00/27437 describe a Group II hyaluronate synthase from *Pasteurella multocida*. Ferretti et al. disclose the hyaluronan synthase operon of *Streptococcus pyogenes*, which is composed of three genes, hasA, hasB, and hasC, that encode hyaluronate synthase, UDP glucose dehydrogenase, and UDP-glucose pyrophosphorylase, respectively (*Proc. Natl. Acad. Sci. USA.* 98, 4658-4663, 2001). WO 99/51265 describes a nucleic acid segment having a coding region for a *Streptococcus equisimilis* hyaluronan synthase.

Bacilli are well established as host cell systems for the production of native and recombinant proteins. It is an object of the present invention to provide methods for producing a hyaluronan in a recombinant *Bacillus* host cell.

BRIEF SUMMARY OF THE INVENTION

The present invention relates to methods for producing a hyaluronic acid, comprising: (a) cultivating a *Bacillus* host cell under conditions suitable for production of the hyaluronic acid, wherein the *Bacillus* host cell comprises a nucleic acid construct comprising a hyaluronan synthase encoding sequence operably linked to a promoter sequence foreign to the hyaluronan synthase encoding sequence; and (b) recovering the hyaluronic acid from the cultivation medium.

In preferred embodiments, the nucleic acid construct further comprises one or more genes encoding enzymes in the biosynthesis of a precursor sugar of the hyaluronic acid or the *Bacillus* host cell further comprises one or more second nucleic acid constructs comprising one or more genes encoding enzymes in the biosynthesis of the precursor sugar.

In another preferred embodiment, the one or more genes encoding a precursor sugar are under the control of the same or a different promoter(s) as the hyaluronan synthase encoding sequence.

The present invention also relates to *Bacillus* host cells comprising a nucleic acid construct comprising a hyaluronan synthase encoding sequence operably linked to a promoter sequence foreign to the hyaluronan synthase encoding sequence, and to such nucleic acid constructs.

The present invention also relates to an isolated nucleic acid sequence encoding a hyaluronan synthase operon comprising a hyaluronan synthase gene or a portion thereof and a UDP-glucose 6-dehydrogenase gene, and optionally one or more genes selected from the group consisting of a UDP-glucose pyrophosphorylase gene, UDP-N-acetylglucosamine pyrophosphorylase gene, and glucose-6-phosphate isomerase gene.

The present invention also relates to isolated nucleic acid sequences encoding a UDP-glucose 6-dehydrogenase selected from the group consisting of: (a) a nucleic acid sequence encoding a polypeptide having an amino acid sequence which has at least about 75%, about 80%, about

85%, about 90%, or about 95% identity to SEQ ID NO: 41; (b) a nucleic acid sequence having at least about 75%, about 80%, about 85%, about 90%, or about 95% homology to SEQ ID NO: 40; (c) a nucleic acid sequence which hybridizes under medium or high stringency conditions with (i) the nucleic acid sequence of SEQ ID NO: 40, (ii) the cDNA sequence contained in SEQ ID NO: 40, or (iii) a complementary strand of (i) or (ii); and (d) a subsequence of (a), (b), or (c), wherein the subsequence encodes a polypeptide fragment which has UDP-glucose 6-dehydrogenase activity.

The present invention also relates to isolated nucleic acid sequences encoding a UDP-glucose pyrophosphorylase selected from the group consisting of: (a) a nucleic acid sequence encoding a polypeptide having an amino acid sequence which has at least about 90%, about 95%, or about 97% identity to SEQ ID NO: 43; (b) a nucleic acid sequence having at least about 90%, about 95%, or about 97% homology to SEQ ID NO: 42; (c) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with (i) the nucleic acid sequence of SEQ ID NO: 42, (ii) the cDNA sequence contained in SEQ ID NO: 42, or (iii) a complementary strand of (i) or (ii); and (d) a subsequence of (a), (b), or (c), wherein the subsequence encodes a polypeptide fragment which has UDP-N-acetylglucosamine pyrophosphorylase activity.

The present invention also relates to isolated nucleic acid sequences encoding a UDP-N-acetylglucosamine pyrophosphorylase selected from the group consisting of: (a) a nucleic acid sequence encoding a polypeptide having an amino acid sequence which has at least about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 45; (b) a nucleic acid sequence having at least about 75%, about 80%, about 85%, about 90%, or about 95% homology to SEQ ID NO: 44; (c) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with (i) the nucleic acid sequence of SEQ ID NO: 44, (ii) the cDNA sequence contained in SEQ ID NO: 44, or (iii) a complementary strand of (i) or (ii); and (d) a subsequence of (a), (b), or (c), wherein the subsequence encodes a polypeptide fragment which has UDP-N-acetylglucosamine pyrophosphorylase activity.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 shows the chemical structure of hyaluronan.
 FIG. 2 shows the biosynthetic pathway for hyaluronan synthesis.
 FIG. 3 shows a restriction map of pCR2.1-sehasA.
 FIG. 4 shows a restriction map of pCR2.1-tuaD.
 FIG. 5 shows a restriction map of pCR2.1-gtaB.
 FIG. 6 shows a restriction map of pCR2.1-gcaD.
 FIG. 7 shows a restriction map of pHA1.
 FIG. 8 shows a restriction map of pHA2.
 FIG. 9 shows a restriction map of pHA3.
 FIG. 10 shows a restriction map of pHA4.
 FIG. 11 shows a restriction map of pHA5.
 FIG. 12 shows a restriction map of pHA6.
 FIG. 13 shows a restriction map of pHA7.
 FIG. 14 shows a restriction map of pMRT106.
 FIG. 15 shows a restriction map of pHA8.
 FIG. 16 shows a restriction map of pHA9.
 FIG. 17 shows a restriction map of pHA10.
 FIG. 18 shows a restriction map of pRB157.
 FIG. 19 shows a restriction map of pMRT084.
 FIG. 20 shows a restriction map of pMRT086.
 FIG. 21 shows a restriction map of pCJ791.
 FIG. 22 shows a restriction map of pMRT032.

FIG. 23 shows a restriction map of pNNB194neo.
 FIG. 24 shows a restriction map of pNNB194neo-oriT.
 FIG. 25 shows a restriction map of pShV3.
 FIG. 26 shows a restriction map of pShV2.1-amyEΔB.
 FIG. 27 shows a restriction map of pShV3A.
 FIG. 28 shows a restriction map of pMRT036.
 FIG. 29 shows a restriction map of pMRT037.
 FIG. 30 shows a restriction map of pMRT041.
 FIG. 31 shows a restriction map of pMRT064.1.
 FIG. 32 shows a restriction map of pMRT068.
 FIG. 33 shows a restriction map of pMRT069.
 FIG. 34 shows a restriction map of pMRT071.
 FIG. 35 shows a restriction map of pMRT074.
 FIG. 36 shows a restriction map of pMRT120.
 FIG. 37 shows a restriction map of pMRT122.
 FIG. 38 shows a restriction map of pCR2.1-pel5'.
 FIG. 39 shows a restriction map of pCR2.1-pel3'.
 FIG. 40 shows a restriction map of pRB161.
 FIG. 41 shows a restriction map of pRB162.
 FIG. 42 shows a restriction map of pRB156.
 FIG. 43 shows a restriction map of pRB164.
 FIG. 44 shows a summary of fermentations of various hyaluronic acid producing *Bacillus subtilis* strains run under fed batch at approximately 2 g sucrose/L₀-hr, 37° C.
 FIG. 45 shows a summary of peak hyaluronic acid weight average molecular weights (MDa) obtained from fermentations of various hyaluronic acid producing *Bacillus subtilis* strains run under fed batch at approximately 2 g sucrose/L₀-hr, 37° C.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to methods for producing a hyaluronan, comprising: (a) cultivating a *Bacillus* host cell under conditions suitable for production of the hyaluronan, wherein the *Bacillus* host cell comprises a nucleic acid construct comprising a hyaluronan synthase encoding sequence operably linked to a promoter sequence foreign to the hyaluronan synthase encoding sequence; and (b) recovering the hyaluronan from the cultivation medium.

The methods of the present invention represent an improvement over the production of hyaluronan from pathogenic, encapsulating bacteria. In encapsulating bacteria, a large quantity of the hyaluronan is produced in the capsule. In processing and purifying hyaluronan from such sources, it is first necessary to remove the hyaluronan from the capsule, such as by the use of a surfactant, or detergent, such as SDS. This creates a complicating step in commercial production of hyaluronan, as the surfactant must be added in order to liberate a large portion of the hyaluronan, and subsequently the surfactant must be removed prior to final purification.

The present invention allows the production of a large quantity of a hyaluronan, which is produced in a non-encapsulating host cell, as free hyaluronan. When viewed under the microscope, there is no visible capsule associated with the recombinant strains of *Bacillus*, whereas the pathogenic strains traditionally used in hyaluronan production comprise a capsule of hyaluronan that is at least twice the diameter of the cell itself.

Since the hyaluronan of the recombinant *Bacillus* cell is expressed directly to the culture medium, a simple process may be used to isolate the hyaluronan from the culture medium. First, the *Bacillus* cells and cellular debris are physically removed from the culture medium. The culture medium may be diluted first, if desired, to reduce the viscosity of the medium. Many methods are known to those skilled in the art for removing cells from culture medium, such as centrifuga-

tion or microfiltration. If desired, the remaining supernatant may then be filtered, such as by ultrafiltration, to concentrate and remove small molecule contaminants from the hyaluronan. Following removal of the cells and cellular debris, a simple precipitation of the hyaluronan from the medium is performed by known mechanisms. Salt, alcohol, or combinations of salt and alcohol may be used to precipitate the hyaluronan from the filtrate. Once reduced to a precipitate, the hyaluronan can be easily isolated from the solution by physical means. Alternatively, the hyaluronan may be dried or concentrated from the filtrate solution by using evaporative techniques known to the art, such as spray drying.

The methods of the present invention thus represent an improvement over existing techniques for commercially producing hyaluronan by fermentation, in not requiring the use of a surfactant in the purification of hyaluronan from cells in culture.

Hyaluronic Acid

“Hyaluronic acid” is defined herein as an unsulphated glycosaminoglycan composed of repeating disaccharide units of N-acetylglucosamine (GlcNAc) and glucuronic acid (GlcUA) linked together by alternating beta-1,4 and beta-1,3 glycosidic bonds (FIG. 1). Hyaluronic acid is also known as hyaluronan, hyaluronate, or HA. The terms hyaluronan and hyaluronic acid are used interchangeably herein.

In a preferred embodiment, the hyaluronic acid obtained by the methods of the present invention has a molecular weight of about 10,000 to about 10,000,000 Da. In a more preferred embodiment, the hyaluronic acid obtained by the methods of the present invention has a molecular weight of about 25,000 to about 5,000,000 Da. In a most preferred embodiment, the hyaluronic acid obtained by the methods of the present invention has a molecular weight of about 50,000 to about 3,000,000 Da.

The level of hyaluronic acid produced by a *Bacillus* host cell of the present invention may be determined according to the modified carbazole method (Bitter and Muir, 1962, *Anal Biochem.* 4: 330-334). Moreover, the average molecular weight of the hyaluronic acid may be determined using standard methods in the art, such as those described by Ueno et al., 1988, *Chem. Pharm. Bull.* 36, 4971-4975; Wyatt, 1993, *Anal. Chim. Acta* 272: 1-40; and Wyatt Technologies, 1999, “Light Scattering University DAWN Course Manual” and “DAWN EOS Manual” Wyatt Technology Corporation, Santa Barbara, Calif.

The hyaluronic acid obtained by the methods of the present invention may be subjected to various techniques known in the art to modify the hyaluronic acid, such as crosslinking as described, for example, in U.S. Pat. Nos. 5,616,568, 5,652,347, and 5,874,417. Moreover, the molecular weight of the hyaluronic acid may be altered using techniques known in the art.

Host Cells

In the methods of the present invention, the *Bacillus* host cell may be any *Bacillus* cell suitable for recombinant production of hyaluronic acid. The *Bacillus* host cell may be a wild-type *Bacillus* cell or a mutant thereof. *Bacillus* cells useful in the practice of the present invention include, but are not limited to, *Bacillus agaraderhens*, *Bacillus alkalophilus*, *Bacillus amyloliquefaciens*, *Bacillus brevis*, *Bacillus circulans*, *Bacillus clausii*, *Bacillus coagulans*, *Bacillus firmus*, *Bacillus lautus*, *Bacillus lentus*, *Bacillus licheniformis*, *Bacillus megaterium*, *Bacillus pumilus*, *Bacillus stearothermophilus*, *Bacillus subtilis*, and *Bacillus thuringiensis* cells. Mutant *Bacillus subtilis* cells particularly adapted for recombinant

expression are described in WO 98/22598. Non-encapsulating *Bacillus* cells are particularly useful in the present invention.

In a preferred embodiment, the *Bacillus* host cell is a *Bacillus amyloliquefaciens*, *Bacillus clausii*, *Bacillus lentus*, *Bacillus licheniformis*, *Bacillus stearothermophilus* or *Bacillus subtilis* cell. In a more preferred embodiment, the *Bacillus* cell is a *Bacillus amyloliquefaciens* cell. In another more preferred embodiment, the *Bacillus* cell is a *Bacillus clausii* cell. In another more preferred embodiment, the *Bacillus* cell is a *Bacillus lentus* cell. In another more preferred embodiment, the *Bacillus* cell is a *Bacillus licheniformis* cell. In another more preferred embodiment, the *Bacillus* cell is a *Bacillus subtilis* cell. In a most preferred embodiment, the *Bacillus* host cell is *Bacillus subtilis* A164Δ5 (see U.S. Pat. No. 5,891,701) or *Bacillus subtilis* 168Δ4.

Transformation of the *Bacillus* host cell with a nucleic acid construct of the present invention may, for instance, be effected by protoplast transformation (see, e.g., Chang and Cohen, 1979, *Molecular General Genetics* 168: 111-115), by using competent cells (see, e.g., Young and Spizizen, 1961, *Journal of Bacteriology* 81: 823-829, or Dubnau and Davidoff-Abelson, 1971, *Journal of Molecular Biology* 56: 209-221), by electroporation (see, e.g., Shigekawa and Dower, 1988, *Biotechniques* 6: 742-751), or by conjugation (see, e.g., Koehler and Thorne, 1987, *Journal of Bacteriology* 169: 5271-5278).

Nucleic Acid Constructs

“Nucleic acid construct” is defined herein as a nucleic acid molecule, either single- or double-stranded, which is isolated from a naturally occurring gene or which has been modified to contain segments of nucleic acid which are combined and juxtaposed in a manner which would not otherwise exist in nature. The term nucleic acid construct may be synonymous with the term expression cassette when the nucleic acid construct contains all the control sequences required for expression of a coding sequence. The term “coding sequence” is defined herein as a sequence which is transcribed into mRNA and translated into an enzyme of interest when placed under the control of the below mentioned control sequences. The boundaries of the coding sequence are generally determined by a ribosome binding site located just upstream of the open reading frame at the 5' end of the mRNA and a transcription terminator sequence located just downstream of the open reading frame at the 3' end of the mRNA. A coding sequence can include, but is not limited to, DNA, cDNA, and recombinant nucleic acid sequences.

The techniques used to isolate or clone a nucleic acid sequence encoding a polypeptide are well known in the art and include, for example, isolation from genomic DNA, preparation from cDNA, or a combination thereof. The cloning of the nucleic acid sequences from such genomic DNA can be effected, e.g., by using antibody screening of expression libraries to detect cloned DNA fragments with shared structural features or the well known polymerase chain reaction (PCR). See, for example, Innis et al., 1990, *PCR Protocols: A Guide to Methods and Application*, Academic Press, New York. Other nucleic acid amplification procedures such as ligase chain reaction, ligated activated transcription, and nucleic acid sequence-based amplification may be used. The cloning procedures may involve excision and isolation of a desired nucleic acid fragment comprising the nucleic acid sequence encoding the polypeptide, insertion of the fragment into a vector molecule, and incorporation of the recombinant vector into a *Bacillus* cell where clones of the nucleic acid

sequence will be replicated. The nucleic acid sequence may be of genomic, cDNA, RNA, semi-synthetic, synthetic origin, or any combinations thereof.

An isolated nucleic acid sequence encoding an enzyme may be manipulated in a variety of ways to provide for expression of the enzyme. Manipulation of the nucleic acid sequence prior to its insertion into a construct or vector may be desirable or necessary depending on the expression vector or *Bacillus* host cell. The techniques for modifying nucleic acid sequences utilizing cloning methods are well known in the art. It will be understood that the nucleic acid sequence may also be manipulated in vivo in the host cell using methods well known in the art.

A number of enzymes are involved in the biosynthesis of hyaluronic acid. These enzymes include hyaluronan synthase, UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, UDP-N-acetylglucosamine pyrophosphorylase, glucose-6-phosphate isomerase, hexokinase, phosphoglucomutase, amidotransferase, mutase, and acetyl transferase. Hyaluronan synthase is the key enzyme in the production of hyaluronic acid.

“Hyaluronan synthase” is defined herein as a synthase that catalyzes the elongation of a hyaluronan chain by the addition of GlcUA and GlcNAc sugar precursors. The amino acid sequences of streptococcal hyaluronan synthases, vertebrate hyaluronan synthases, and the viral hyaluronan synthase are distinct from the *Pasteurella* hyaluronan synthase, and have been proposed for classification as Group I and Group II hyaluronan synthases, the Group I hyaluronan synthases including Streptococcal hyaluronan synthases (DeAngelis, 1999). For production of hyaluronan in *Bacillus* host cells, hyaluronan synthases of a eukaryotic origin, such as mammalian hyaluronan synthases, are less preferred.

The hyaluronan synthase encoding sequence may be any nucleic acid sequence capable of being expressed in a *Bacillus* host cell. The nucleic acid sequence may be of any origin. Preferred hyaluronan synthase genes include any of either Group I or Group II, such as the Group I hyaluronan synthase genes from *Streptococcus equisimilis*, *Streptococcus pyogenes*, *Streptococcus uberis*, and *Streptococcus equi* subsp. *zooepidemicus*, or the Group II hyaluronan synthase genes of *Pasteurella multocida*.

In a preferred embodiment, the hyaluronan synthase encoding sequence is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 2, SEQ ID NO: 93, or SEQ ID NO: 103; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 1, SEQ ID NO: 92, or SEQ ID NO: 102; and (c) a complementary strand of (a) or (b).

In a more preferred embodiment, the hyaluronan synthase encoding sequence encodes a polypeptide having the amino acid sequence of SEQ ID NO: 2, SEQ ID NO: 93, or SEQ ID NO: 103; or a fragment thereof having hyaluronan synthase activity.

In another preferred embodiment, the hyaluronan synthase encoding sequence is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 95; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 94; and (c) a complementary strand of (a) or (b).

In another more preferred embodiment, the hyaluronan synthase encoding sequence encodes a polypeptide having

the amino acid sequence of SEQ ID NO: 95, or a fragment thereof having hyaluronan synthase activity.

The methods of the present invention also include constructs whereby precursor sugars of hyaluronan are supplied to the host cell, either to the culture medium, or by being encoded by endogenous genes, by non-endogenous genes, or by a combination of endogenous and non-endogenous genes in the *Bacillus* host cell. The precursor sugar may be D-glucuronic acid or N-acetyl-glucosamine.

In the methods of the present invention, the nucleic acid construct may further comprise one or more genes encoding enzymes in the biosynthesis of a precursor sugar of a hyaluronan. Alternatively, the *Bacillus* host cell may further comprise one or more second nucleic acid constructs comprising one or more genes encoding enzymes in the biosynthesis of the precursor sugar. Hyaluronan production is improved by the use of constructs with a nucleic acid sequence or sequences encoding a gene or genes directing a step in the synthesis pathway of the precursor sugar of hyaluronan. By, “directing a step in the synthesis pathway of a precursor sugar of hyaluronan” is meant that the expressed protein of the gene is active in the formation of N-acetyl-glucosamine or D-glucuronic acid, or a sugar that is a precursor of either of N-acetyl-glucosamine and D-glucuronic acid (FIG. 2).

In a preferred method for supplying precursor sugars, constructs are provided for improving hyaluronan production in a host cell having a hyaluronan synthase, by culturing a host cell having a recombinant construct with a heterologous promoter region operably linked to a nucleic acid sequence encoding a gene directing a step in the synthesis pathway of a precursor sugar of hyaluronan. In a preferred method the host cell also comprises a recombinant construct having a promoter region operably linked to a hyaluronan synthase, which may use the same or a different promoter region than the nucleic acid sequence to a synthase involved in the biosynthesis of N-acetyl-glucosamine. In a further preferred embodiment, the host cell may have a recombinant construct with a promoter region operably linked to different nucleic acid sequences encoding a second gene involved in the synthesis of a precursor sugar of hyaluronan.

Thus, the present invention also relates to constructs for improving hyaluronan production by the use of constructs with a nucleic acid sequence encoding a gene directing a step in the synthesis pathway of a precursor sugar of hyaluronan. The nucleic acid sequence to the precursor sugar may be expressed from the same or a different promoter as the nucleic acid sequence encoding the hyaluronan synthase.

The genes involved in the biosynthesis of precursor sugars for the production of hyaluronic acid include a UDP-glucose 6-dehydrogenase gene, UDP-glucose pyrophosphorylase gene, UDP-N-acetylglucosamine pyrophosphorylase gene, glucose-6-phosphate isomerase gene, hexokinase gene, phosphoglucomutase gene, amidotransferase gene, mutase gene, and acetyl transferase gene.

In a cell containing a hyaluronan synthase, any one or combination of two or more of hasB, hasC and hasD, or the homologs thereof, such as the *Bacillus subtilis* tuaD, gtaB, and gcaD, respectively, as well as hasE, may be expressed to increase the pools of precursor sugars available to the hyaluronan synthase. The *Bacillus* genome is described in Kunst, et al., Nature 390, 249-256, “The complete genome sequence of the Gram-positive bacterium *Bacillus subtilis*” (20 Nov. 1997). In some instances, such as where the host cell does not have a native hyaluronan synthase activity, the construct may include the hasA gene.

The nucleic acid sequence encoding the biosynthetic enzymes may be native to the host cell, while in other cases

heterologous sequence may be utilized. If two or more genes are expressed they may be genes that are associated with one another in a native operon, such as the genes of the HAS operon of *Streptococcus equisimilis*, which comprises hasA, hasB, hasC and hasD. In other instances, the use of some combination of the precursor gene sequences may be desired, without each element of the operon included. The use of some genes native to the host cell, and others which are exogenous may also be preferred in other cases. The choice will depend on the available pools of sugars in a given host cell, the ability of the cell to accommodate overproduction without interfering with other functions of the host cell, and whether the cell regulates expression from its native genes differently than exogenous genes.

As one example, depending on the metabolic requirements and growth conditions of the cell, and the available precursor sugar pools, it may be desirable to increase the production of N-acetyl-glucosamine by expression of a nucleic acid sequence encoding UDP-N-acetylglucosamine pyrophosphorylase, such as the hasD gene, the *Bacillus gcaD* gene, and homologs thereof. Alternatively, the precursor sugar may be D-glucuronic acid. In one such embodiment, the nucleic acid sequence encodes UDP-glucose 6-dehydrogenase. Such nucleic acid sequences include the *Bacillus tuaD* gene, the hasB gene of *Streptococcus*, and homologs thereof. The nucleic acid sequence may also encode UDP-glucose pyrophosphorylase, such as in the *Bacillus gtaB* gene, the hasC gene of *Streptococcus*, and homologs thereof.

In the methods of the present invention, the UDP-glucose 6-dehydrogenase gene may be a hasB gene or tuaD gene; or homologs thereof.

In a preferred embodiment, the hasB gene is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 41, SEQ ID NO: 97, or SEQ ID NO: 105; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 40, SEQ ID NO: 96, or SEQ ID NO: 104; and (c) a complementary strand of (a) or (b).

In a more preferred embodiment, the hasB gene encodes a polypeptide having the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 97, or SEQ ID NO: 105; or a fragment thereof having UDP-glucose 6-dehydrogenase activity.

In another preferred embodiment, the tuaD gene is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 12; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 11; and (c) a complementary strand of (a) or (b).

In another more preferred embodiment, the tuaD gene encodes a polypeptide having the amino acid sequence of SEQ ID NO: 12, or a fragment thereof having UDP-glucose 6-dehydrogenase activity.

In the methods of the present invention, the UDP-glucose pyrophosphorylase gene may be a hasC gene or gtaB gene; or homologs thereof.

In a preferred embodiment, the hasC gene is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 43, SEQ ID NO: 99, or SEQ ID NO: 107; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with

SEQ ID NO: 42 or SEQ ID NO: 98, or SEQ ID NO: 106; and (c) a complementary strand of (a) or (b).

In another more preferred embodiment, the hasC gene encodes a polypeptide having the amino acid sequence of SEQ ID NO: 43 or SEQ ID NO: 99, or SEQ ID NO: 107; or a fragment thereof having UDP-glucose pyrophosphorylase activity.

In another preferred embodiment, the gtaB gene is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 22; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 21; and (c) a complementary strand of (a) or (b).

In another more preferred embodiment, the gtaB gene encodes a polypeptide having the amino acid sequence of SEQ ID NO: 22, or a fragment thereof having UDP-glucose pyrophosphorylase activity.

In the methods of the present invention, the UDP-N-acetylglucosamine pyrophosphorylase gene may be a hasD or gcaD gene; or homologs thereof.

In a preferred embodiment, the hasD gene is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 45; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 44; and (c) a complementary strand of (a) or (b).

In another more preferred embodiment, the hasD gene encodes a polypeptide having the amino acid sequence of SEQ ID NO: 45, or a fragment thereof having UDP-N-acetylglucosamine pyrophosphorylase activity.

In another preferred embodiment, the gcaD gene is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 30; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 29; and (c) a complementary strand of (a) or (b).

In another more preferred embodiment, the gcaD gene encodes a polypeptide having the amino acid sequence of SEQ ID NO: 30, or a fragment thereof having UDP-N-acetylglucosamine pyrophosphorylase activity.

In the methods of the present invention, the glucose-6-phosphate isomerase gene may be a hasE or homolog thereof.

In a preferred embodiment, the hasE gene is selected from the group consisting of (a) a nucleic acid sequence encoding a polypeptide with an amino acid sequence having at least about 70%, about 75%, about 80%, about 85%, about 90%, or about 95% identity to SEQ ID NO: 101; (b) a nucleic acid sequence which hybridizes under low, medium, or high stringency conditions with SEQ ID NO: 100; and (c) a complementary strand of (a) or (b).

In another more preferred embodiment, the hasE gene encodes a polypeptide having the amino acid sequence of SEQ ID NO: 101, or a fragment thereof having glucose-6-phosphate isomerase activity.

In the methods of the present invention, the hyaluronan synthase gene and the one or more genes encoding a precursor sugar are under the control of the same promoter. Alternatively, the one or more genes encoding a precursor sugar are under the control of the same promoter but a different promoter driving the hyaluronan synthase gene. A further alternative is that the hyaluronan synthase gene and each of the

genes encoding a precursor sugar are under the control of different promoters. In a preferred embodiment, the hyaluronan synthase gene and the one or more genes encoding a precursor sugar are under the control of the same promoter.

The present invention also relates to a nucleic acid construct comprising an isolated nucleic acid sequence encoding a hyaluronan synthase operon comprising a hyaluronan synthase gene and a UDP-glucose 6-dehydrogenase gene, and optionally one or more genes selected from the group consisting of a UDP-glucose pyrophosphorylase gene, UDP-N-acetylglucosamine pyrophosphorylase gene, and glucose-6-phosphate isomerase gene. A nucleic acid sequence encoding most of the hyaluronan synthase operon of *Streptococcus equisimilis* is found in SEQ ID NO: 108. This sequence contains the hasB (SEQ ID NO: 40) and hasC (SEQ ID NO: 42) homologs of the *Bacillus subtilis* tuaD gene (SEQ ID NO: 11) and gtaB gene (SEQ ID NO: 21), respectively, as is the case for *Streptococcus pyogenes*, as well as a homolog of the gcaD gene (SEQ ID NO: 29), which has been designated hasD (SEQ ID NO: 44). The *Bacillus subtilis* gcaD encodes UDP-N-acetylglucosamine pyrophosphorylase, which is involved in the synthesis of N-acetyl-glucosamine, one of the two sugars of hyaluronan. The *Streptococcus equisimilis* homolog of gcaD, hasD, is arranged by *Streptococcus equisimilis* on the hyaluronan synthase operon. The nucleic acid sequence also contains a portion of the hasA gene (the last 1156 bp of SEQ ID NO: 1).

In some cases the host cell will have a recombinant construct with a heterologous promoter region operably linked to a nucleic acid sequence encoding a gene directing a step in the synthesis pathway of a precursor sugar of hyaluronan, which may be in concert with the expression of hyaluronan synthase from a recombinant construct. The hyaluronan synthase may be expressed from the same or a different promoter region than the nucleic acid sequence encoding an enzyme involved in the biosynthesis of the precursor. In another preferred embodiment, the host cell may have a recombinant construct with a promoter region operably linked to a different nucleic acid sequence encoding a second gene involved in the synthesis of a precursor sugar of hyaluronan.

The nucleic acid sequence encoding the enzymes involved in the biosynthesis of the precursor sugar(s) may be expressed from the same or a different promoter as the nucleic acid sequence encoding the hyaluronan synthase. In the former sense, "artificial operons" are constructed, which may mimic the operon of *Streptococcus equisimilis* in having each hasA, hasB, hasC and hasD, or homologs thereof, or, alternatively, may utilize less than the full complement present in the *Streptococcus equisimilis* operon. The "artificial operons" may also comprise a glucose-6-phosphate isomerase gene (hasE) as well as one or more genes selected from the group consisting of a hexokinase gene, phosphoglucomutase gene, amidotransferase gene, mutase gene, and acetyl transferase gene. In the artificial operon, at least one of the elements is heterologous to one other of the elements, such as the promoter region being heterologous to the encoding sequences.

In a preferred embodiment, the nucleic acid construct comprises hasA, tuaD, and gtaB. In another preferred embodiment, the nucleic acid construct comprises hasA, tuaD, gtaB, and gcaD. In another preferred embodiment, the nucleic acid construct comprises hasA and tuaD. In another preferred embodiment, the nucleic acid construct comprises hasA. In another preferred embodiment, the nucleic acid construct comprises hasA, tuaD, gtaB, gcaD, and hasE.

In another preferred embodiment, the nucleic acid construct comprises hasA, hasB, hasC, and hasD. In another preferred embodiment, the nucleic acid construct comprises

hasA, hasB, hasC, hasD, and hasE. Based on the above preferred embodiments, the genes noted can be replaced with homologs thereof.

In the methods of the present invention, the nucleic acid constructs comprise a hyaluronan synthase encoding sequence operably linked to a promoter sequence foreign to the hyaluronan synthase encoding sequence. The promoter sequence may be, for example, a single promoter or a tandem promoter.

"Promoter" is defined herein as a nucleic acid sequence involved in the binding of RNA polymerase to initiate transcription of a gene. "Tandem promoter" is defined herein as two or more promoter sequences each of which is operably linked to a coding sequence and mediates the transcription of the coding sequence into mRNA. "Operably linked" is defined herein as a configuration in which a control sequence, e.g., a promoter sequence, is appropriately placed at a position relative to a coding sequence such that the control sequence directs the production of a polypeptide encoded by the coding sequence. As noted earlier, a "coding sequence" is defined herein as a nucleic acid sequence which is transcribed into mRNA and translated into a polypeptide when placed under the control of the appropriate control sequences. The boundaries of the coding sequence are generally determined by a ribosome binding site located just upstream of the open reading frame at the 5' end of the mRNA and a transcription terminator sequence located just downstream of the open reading frame at the 3' end of the mRNA. A coding sequence can include, but is not limited to, genomic DNA, cDNA, semisynthetic, synthetic, and recombinant nucleic acid sequences.

In a preferred embodiment, the promoter sequences may be obtained from a bacterial source. In a more preferred embodiment, the promoter sequences may be obtained from a gram positive bacterium such as a *Bacillus* strain, e.g., *Bacillus agaradherens*, *Bacillus alkalophilus*, *Bacillus amyloliquefaciens*, *Bacillus brevis*, *Bacillus circulans*, *Bacillus clausii*, *Bacillus coagulans*, *Bacillus firmus*, *Bacillus lautus*, *Bacillus lentus*, *Bacillus licheniformis*, *Bacillus megaterium*, *Bacillus pumilus*, *Bacillus stearothermophilus*, *Bacillus subtilis*, or *Bacillus thuringiensis*; or a *Streptomyces* strain, e.g., *Streptomyces lividans* or *Streptomyces murinus*; or from a gram negative bacterium, e.g., *E. coli* or *Pseudomonas* sp.

Examples of suitable promoters for directing the transcription of a nucleic acid sequence in the methods of the present invention are the promoters obtained from the *E. coli* lac operon, *Streptomyces coelicolor* agarase gene (dagA), *Bacillus lentus* or *Bacillus clausii* alkaline protease gene (aprH), *Bacillus licheniformis* alkaline protease gene (subtilisin Carlsberg gene), *Bacillus subtilis* levansucrase gene (sacB), *Bacillus subtilis* alpha-amylase gene (amyE), *Bacillus licheniformis* alpha-amylase gene (amyL), *Bacillus stearothermophilus* maltogenic amylase gene (amyM), *Bacillus amyloliquefaciens* alpha-amylase gene (amyQ), *Bacillus licheniformis* penicillinase gene (penP), *Bacillus subtilis* xylA and xylB genes, *Bacillus thuringiensis* subsp. *tenebrionis* CryIIIa gene (cryIIIa) or portions thereof, prokaryotic beta-lactamase gene (VIIIa-Kamaroff et al., 1978, *Proceedings of the National Academy of Sciences USA* 75:3727-3731). Other examples are the promoter of the spol bacterial phage promoter and the tac promoter (DeBoer et al., 1983, *Proceedings of the National Academy of Sciences USA* 80:21-25). Further promoters are described in "Useful proteins from recombinant bacteria" in *Scientific American*, 1980, 242:74-94; and in Sambrook, Fritsch, and Maniatus, 1989, *Molecular Cloning, A Laboratory Manual*, 2d edition, Cold Spring Harbor, N.Y.

The promoter may also be a "consensus" promoter having the sequence TTGACA for the "-35" region and TATAAT for the "-10" region. The consensus promoter may be obtained from any promoter which can function in a *Bacillus* host cell. The construction of a "consensus" promoter may be accomplished by site-directed mutagenesis to create a promoter which conforms more perfectly to the established consensus sequences for the "-10" and "-35" regions of the vegetative "sigma A-type" promoters for *Bacillus subtilis* (Voskuil et al., 1995, *Molecular Microbiology* 17: 271-279).

In a preferred embodiment, the "consensus" promoter is obtained from a promoter obtained from the *E. coli* lac operon, *Streptomyces coelicolor* agarase gene (dagA), *Bacillus clausii* or *Bacillus lentus* alkaline protease gene (aprH), *Bacillus licheniformis* alkaline protease gene (subtilisin Carlsberg gene), *Bacillus subtilis* levansucrase gene (sacB), *Bacillus subtilis* alpha-amylase gene (amyE), *Bacillus licheniformis* alpha-amylase gene (amyL), *Bacillus stearothermophilus* maltogenic amylase gene (amyM), *Bacillus amyloliquefaciens* alpha-amylase gene (amyQ), *Bacillus licheniformis* penicillinase gene (penP), *Bacillus subtilis* xylA and xylB genes, *Bacillus thuringiensis* subsp. *tenebrionis* CryIIIA gene (ctyIIIA) or portions thereof, or prokaryotic beta-lactamase gene spol bacterial phage promoter. In a more preferred embodiment, the "consensus" promoter is obtained from *Bacillus amyloliquefaciens* alpha-amylase gene (amyQ).

Widner, et al., U.S. Pat. Nos. 6,255,076 and 5,955,310, describe tandem promoters and constructs and methods for use in expression in *Bacillus* cells, including the short consensus amyQ promoter (also called scBAN). The use of the cryIIIA stabilizer sequence, and constructs using the sequence, for improved production in *Bacillus* are also described therein.

Each promoter sequence of the tandem promoter may be any nucleic acid sequence which shows transcriptional activity in the *Bacillus* cell of choice including a mutant, truncated, and hybrid promoter, and may be obtained from genes encoding extracellular or intracellular polypeptides either homologous or heterologous to the *Bacillus* cell. Each promoter sequence may be native or foreign to the nucleic acid sequence encoding the polypeptide and native or foreign to the *Bacillus* cell. The promoter sequences may be the same promoter sequence or different promoter sequences.

The two or more promoter sequences of the tandem promoter may simultaneously promote the transcription of the nucleic acid sequence. Alternatively, one or more of the promoter sequences of the tandem promoter may promote the transcription of the nucleic acid sequence at different stages of growth of the *Bacillus* cell.

In a preferred embodiment, the tandem promoter contains at least the amyQ promoter of the *Bacillus amyloliquefaciens* alpha-amylase gene. In another preferred embodiment, the tandem promoter contains at least a "consensus" promoter having the sequence TTGACA for the "-35" region and TATAAT for the "-10" region. In another preferred embodiment, the tandem promoter contains at least the amyL promoter of the *Bacillus licheniformis* alpha-amylase gene. In another preferred embodiment, the tandem promoter contains at least the ctyIIIA promoter or portions thereof (Agaisse and Lereclus, 1994, *Molecular Microbiology* 13: 97-107).

In a more preferred embodiment, the tandem promoter contains at least the amyL promoter and the cryIIIA promoter. In another more preferred embodiment, the tandem promoter contains at least the amyQ promoter and the ctyIIIA promoter. In another more preferred embodiment, the tandem promoter contains at least a "consensus" promoter having the

sequence TTGACA for the "-35" region and TATAAT for the "-10" region and the cryIIIA promoter. In another more preferred embodiment, the tandem promoter contains at least two copies of the amyL promoter. In another more preferred embodiment, the tandem promoter contains at least two copies of the amyQ promoter. In another more preferred embodiment, the tandem promoter contains at least two copies of a "consensus" promoter having the sequence TTGACA for the "-35" region and TATAAT for the "-10" region. In another more preferred embodiment, the tandem promoter contains at least two copies of the ctyIIIA promoter.

"An mRNA processing/stabilizing sequence" is defined herein as a sequence located downstream of one or more promoter sequences and upstream of a coding sequence to which each of the one or more promoter sequences are operably linked such that all mRNAs synthesized from each promoter sequence may be processed to generate mRNA transcripts with a stabilizer sequence at the 5' end of the transcripts. The presence of such a stabilizer sequence at the 5' end of the mRNA transcripts increases their half-life (Agaisse and Lereclus, 1994, supra, Hue et al., 1995, *Journal of Bacteriology* 177: 3465-3471). The mRNA processing/stabilizing sequence is complementary to the 3' extremity of a bacterial 16S ribosomal RNA. In a preferred embodiment, the mRNA processing/stabilizing sequence generates essentially single-size transcripts with a stabilizing sequence at the 5' end of the transcripts. The mRNA processing/stabilizing sequence is preferably one, which is complementary to the 3' extremity of a bacterial 16S ribosomal RNA. See, U.S. Pat. Nos. 6,255,076 and 5,955,310.

In a more preferred embodiment, the mRNA processing/stabilizing sequence is the *Bacillus thuringiensis* cryIIIA mRNA processing/stabilizing sequence disclosed in WO 94/25612 and Agaisse and Lereclus, 1994, supra, or portions thereof which retain the mRNA processing/stabilizing function. In another more preferred embodiment, the mRNA processing/stabilizing sequence is the *Bacillus subtilis* SP82 mRNA processing/stabilizing sequence disclosed in Hue et al., 1995, supra, or portions thereof which retain the mRNA processing/stabilizing function.

When the ctyIIIA promoter and its mRNA processing/stabilizing sequence are employed in the methods of the present invention, a DNA fragment containing the sequence disclosed in WO 94/25612 and Agaisse and Lereclus, 1994, supra, or portions thereof which retain the promoter and mRNA processing/stabilizing functions, may be used. Furthermore, DNA fragments containing only the cryIIIA promoter or only the cryIIIA mRNA processing/stabilizing sequence may be prepared using methods well known in the art to construct various tandem promoter and mRNA processing/stabilizing sequence combinations. In this embodiment, the ctyIIIA promoter and its mRNA processing/stabilizing sequence are preferably placed downstream of the other promoter sequence(s) constituting the tandem promoter and upstream of the coding sequence of the gene of interest.

The isolated nucleic acid sequence encoding the desired enzyme(s) involved in hyaluronic acid production may then be further manipulated to improve expression of the nucleic acid sequence. Expression will be understood to include any step involved in the production of the polypeptide including, but not limited to, transcription, post-transcriptional modification, translation, post-translational modification, and secretion. The techniques for modifying nucleic acid sequences utilizing cloning methods are well known in the art.

A nucleic acid construct comprising a nucleic acid sequence encoding an enzyme may be operably linked to one or more control sequences capable of directing the expression

of the coding sequence in a *Bacillus* cell under conditions compatible with the control sequences.

The term "control sequences" is defined herein to include all components which are necessary or advantageous for expression of the coding sequence of a nucleic acid sequence. Each control sequence may be native or foreign to the nucleic acid sequence encoding the enzyme. In addition to promoter sequences described above, such control sequences include, but are not limited to, a leader, a signal sequence, and a transcription terminator. At a minimum, the control sequences include a promoter, and transcriptional and translational stop signals. The control sequences may be provided with linkers for the purpose of introducing specific restriction sites facilitating ligation of the control sequences with the coding region of the nucleic acid sequence encoding an enzyme.

The control sequence may also be a suitable transcription terminator sequence, a sequence recognized by a *Bacillus* cell to terminate transcription. The terminator sequence is operably linked to the 3' terminus of the nucleic acid sequence encoding the enzyme or the last enzyme of an operon. Any terminator which is functional in the *Bacillus* cell of choice may be used in the present invention.

The control sequence may also be a suitable leader sequence, a nontranslated region of a mRNA which is important for translation by the *Bacillus* cell. The leader sequence is operably linked to the 5' terminus of the nucleic acid sequence encoding the enzyme. Any leader sequence which is functional in the *Bacillus* cell of choice may be used in the present invention.

The control sequence may also be a signal peptide coding region, which codes for an amino acid sequence linked to the amino terminus of a polypeptide which can direct the expressed polypeptide into the cell's secretory pathway. The signal peptide coding region may be native to the polypeptide or may be obtained from foreign sources. The 5' end of the coding sequence of the nucleic acid sequence may inherently contain a signal peptide coding region naturally linked in translation reading frame with the segment of the coding region which encodes the secreted polypeptide. Alternatively, the 5' end of the coding sequence may contain a signal peptide coding region which is foreign to that portion of the coding sequence which encodes the secreted polypeptide. The foreign signal peptide coding region may be required where the coding sequence does not normally contain a signal peptide coding region. Alternatively, the foreign signal peptide coding region may simply replace the natural signal peptide coding region in order to obtain enhanced secretion of the polypeptide relative to the natural signal peptide coding region normally associated with the coding sequence. The signal peptide coding region may be obtained from an amylase or a protease gene from a *Bacillus* species. However, any signal peptide coding region capable of directing the expressed polypeptide into the secretory pathway of a *Bacillus* cell of choice may be used in the present invention.

An effective signal peptide coding region for *Bacillus* cells is the signal peptide coding region obtained from the maltogenic amylase gene from *Bacillus* NCIB 11837, the *Bacillus stearothermophilus* alpha-amylase gene, the *Bacillus licheniformis* subtilisin gene, the *Bacillus licheniformis* beta-lactamase gene, the *Bacillus stearothermophilus* neutral proteases genes (nprT, nprS, nprM), and the *Bacillus subtilis* prsA gene. Further signal peptides are described by Simonen and Palva, 1993, *Microbiological Reviews* 57:109-137.

The control sequence may also be a propeptide coding region that codes for an amino acid sequence positioned at the amino terminus of a polypeptide. The resultant polypeptide is

known as a proenzyme or propolypeptide (or a zymogen in some cases). A propolypeptide is generally inactive and can be converted to a mature active polypeptide by catalytic or autocatalytic cleavage of the propeptide from the propolypeptide. The propeptide coding region may be obtained from the genes for *Bacillus subtilis* alkaline protease (aprE) and *Bacillus subtilis* neutral protease (nprT).

Where both signal peptide and propeptide regions are present at the amino terminus of a polypeptide, the propeptide region is positioned next to the amino terminus of a polypeptide and the signal peptide region is positioned next to the amino terminus of the propeptide region.

It may also be desirable to add regulatory sequences which allow the regulation of the expression of the polypeptide relative to the growth of the host cell. Examples of regulatory systems are those which cause the expression of the gene to be turned on or off in response to a chemical or physical stimulus, including the presence of a regulatory compound. Regulatory systems in prokaryotic systems include the lac, tac, and trp operator systems.

Expression Vectors

In the methods of the present invention, a recombinant expression vector comprising a nucleic acid sequence, a promoter, and transcriptional and translational stop signals may be used for the recombinant production of an enzyme involved in hyaluronic acid production. The various nucleic acid and control sequences described above may be joined together to produce a recombinant expression vector which may include one or more convenient restriction sites to allow for insertion or substitution of the nucleic acid sequence encoding the polypeptide or enzyme at such sites. Alternatively, the nucleic acid sequence may be expressed by inserting the nucleic acid sequence or a nucleic acid construct comprising the sequence into an appropriate vector for expression. In creating the expression vector, the coding sequence is located in the vector so that the coding sequence is operably linked with the appropriate control sequences for expression, and possibly secretion.

The recombinant expression vector may be any vector which can be conveniently subjected to recombinant DNA procedures and can bring about the expression of the nucleic acid sequence. The choice of the vector will typically depend on the compatibility of the vector with the *Bacillus* cell into which the vector is to be introduced. The vectors may be linear or closed circular plasmids. The vector may be an autonomously replicating vector, i.e., a vector which exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication, e.g., a plasmid, an extrachromosomal element, a minichromosome, or an artificial chromosome. The vector may contain any means for assuring self-replication. Alternatively, the vector may be one which, when introduced into the *Bacillus* cell, is integrated into the genome and replicated together with the chromosome(s) into which it has been integrated. The vector system may be a single vector or plasmid or two or more vectors or plasmids which together contain the total DNA to be introduced into the genome of the *Bacillus* cell, or a transposon may be used.

The vectors of the present invention preferably contain an element(s) that permits integration of the vector into the *Bacillus* host cell's genome or autonomous replication of the vector in the cell independent of the genome.

For integration into the host cell genome, the vector may rely on the nucleic acid sequence encoding the polypeptide or any other element of the vector for integration of the vector into the genome by homologous or nonhomologous recombination. Alternatively, the vector may contain additional nucleic acid sequences for directing integration by homolo-

gous recombination into the genome of the *Bacillus* cell. The additional nucleic acid sequences enable the vector to be integrated into the *Bacillus* cell genome at a precise location in the chromosome. To increase the likelihood of integration at a precise location, the integrational elements should preferably contain a sufficient number of nucleic acids, such as 100 to 1,500 base pairs, preferably 400 to 1,500 base pairs, and most preferably 800 to 1,500 base pairs, which are highly homologous with the corresponding target sequence to enhance the probability of homologous recombination. The integrational elements may be any sequence that is homologous with the target sequence in the genome of the *Bacillus* cell. Furthermore, the integrational elements may be non-encoding or encoding nucleic acid sequences. On the other hand, the vector may be integrated into the genome of the host cell by non-homologous recombination.

For autonomous replication, the vector may further comprise an origin of replication enabling the vector to replicate autonomously in the *Bacillus* cell in question. Examples of bacterial origins of replication are the origins of replication of plasmids pUB110, pE194, pTA1060, and pAM β 1 permitting replication in *Bacillus*. The origin of replication may be one having a mutation to make its function temperature-sensitive in the *Bacillus* cell (see, e.g., Ehrlich, 1978, *Proceedings of the National Academy of Sciences USA* 75:1433).

The vectors preferably contain one or more selectable markers which permit easy selection of transformed cells. A selectable marker is a gene the product of which provides for biocide resistance, resistance to heavy metals, prototrophy to auxotrophs, and the like. Examples of bacterial selectable markers are the *dal* genes from *Bacillus subtilis* or *Bacillus licheniformis*, or markers which confer antibiotic resistance such as ampicillin, kanamycin, chloramphenicol or tetracycline resistance. Furthermore, selection may be accomplished by co-transformation, e.g., as described in WO 91/09129, where the selectable marker is on a separate vector.

More than one copy of a nucleic acid sequence may be inserted into the host cell to increase production of the gene product. An increase in the copy number of the nucleic acid sequence can be obtained by integrating at least one additional copy of the sequence into the host cell genome or by including an amplifiable selectable marker gene with the nucleic acid sequence where cells containing amplified copies of the selectable marker gene, and thereby additional copies of the nucleic acid sequence, can be selected for by cultivating the cells in the presence of the appropriate selectable agent. A convenient method for achieving amplification of genomic DNA sequences is described in WO 94/14968.

The procedures used to ligate the elements described above to construct the recombinant expression vectors are well known to one skilled in the art (see, e.g., Sambrook et al., 1989, *supra*).

Production

In the methods of the present invention, the *Bacillus* host cells are cultivated in a nutrient medium suitable for production of the hyaluronic acid using methods known in the art. For example, the cell may be cultivated by shake flask cultivation, small-scale or large-scale fermentation (including continuous, batch, fed-batch, or solid state fermentations) in laboratory or industrial fermentors performed in a suitable medium and under conditions allowing the enzymes involved in hyaluronic acid synthesis to be expressed and the hyaluronic acid to be isolated. The cultivation takes place in a suitable nutrient medium comprising carbon and nitrogen sources and inorganic salts, using procedures known in the art. Suitable media are available from commercial suppliers or may be prepared according to published compositions

(e.g., in catalogues of the American Type Culture Collection). The secreted hyaluronic acid can be recovered directly from the medium.

The resulting hyaluronic acid may be isolated by methods known in the art. For example, the hyaluronic acid may be isolated from the nutrient medium by conventional procedures including, but not limited to, centrifugation, filtration, extraction, spray-drying, evaporation, or precipitation. The isolated hyaluronic acid may then be further purified by a variety of procedures known in the art including, but not limited to, chromatography (e.g., ion exchange, affinity, hydrophobic, chromatofocusing, and size exclusion), electrophoretic procedures (e.g., preparative isoelectric focusing), differential solubility (e.g., ammonium sulfate precipitation), or extraction (see, e.g., *Protein Purification*, J.-C. Janson and Lars Ryden, editors, VCH Publishers, New York, 1989).

In the methods of the present invention, the *Bacillus* host cells produce greater than about 4 g, preferably greater than about 6 g, more preferably greater than about 8 g, even more preferably greater than about 10 g, and most preferably greater than about 12 g of hyaluronic acid per liter.

Deletions/Disruptions

Gene deletion or replacement techniques may be used for the complete removal of a selectable marker gene or other undesirable gene. In such methods, the deletion of the selectable marker gene may be accomplished by homologous recombination using a plasmid that has been constructed to contiguously contain the 5' and 3' regions flanking the selectable marker gene. The contiguous 5' and 3' regions may be introduced into a *Bacillus* cell on a temperature-sensitive plasmid, e.g., pE194, in association with a second selectable marker at a permissive temperature to allow the plasmid to become established in the cell. The cell is then shifted to a non-permissive temperature to select for cells that have the plasmid integrated into the chromosome at one of the homologous flanking regions. Selection for integration of the plasmid is effected by selection for the second selectable marker. After integration, a recombination event at the second homologous flanking region is stimulated by shifting the cells to the permissive temperature for several generations without selection. The cells are plated to obtain single colonies and the colonies are examined for loss of both selectable markers (see, for example, Perego, 1993, In A. L. Sonneshein, J. A. Hoch, and R. Losick, editors, *Bacillus subtilis and Other Gram-Positive Bacteria*, Chapter 42, American Society of Microbiology, Washington, D.C., 1993).

A selectable marker gene may also be removed by homologous recombination by introducing into the mutant cell a nucleic acid fragment comprising 5' and 3' regions of the defective gene, but lacking the selectable marker gene, followed by selecting on the counter-selection medium. By homologous recombination, the defective gene containing the selectable marker gene is replaced with the nucleic acid fragment lacking the selectable marker gene. Other methods known in the art may also be used.

U.S. Pat. No. 5,891,701 discloses techniques for deleting several genes including *spoIIAC*, *aprE*, *nprE*, and *amyE*.

Other undesirable biological compounds may also be removed by the above described methods such as the red pigment synthesized by *cypX* (accession no. BG12580) and/or *yvmC* (accession no. BG14121).

In a preferred embodiment, the *Bacillus* host cell is unmarked with any heterologous or exogenous selectable markers. In another preferred embodiment, the *Bacillus* host cell does not produce any red pigment synthesized by *cypX* and *yvmC*.

Isolated Nucleic Acid Sequences Encoding Polypeptides Having UDP-Glucose 6-Dehydrogenase Activity, UDP-Glucose Pyrophosphorylase Activity, or UDP-N-Acetylglucosamine Pyrophosphorylase Activity

The term "UDP-glucose 6-dehydrogenase activity" is defined herein as a UDP glucose:NAD⁺ 6-oxidoreductase activity which catalyzes the conversion of UDP-glucose in the presence of 2NAD⁺ and water to UDP-glucuronate and 2NADH. For purposes of the present invention UDP-glucose 6-dehydrogenase activity is determined according to the procedure described by Jaenicke and Rudolph, 1986, *Biochemistry* 25: 7283-7287. One unit of UDP-glucose 6-dehydrogenase activity is defined as 1.0 μmole of UDP-glucuronate produced per minute at 25° C., pH 7.

The term "UDP-glucose pyrophosphorylase activity" is defined herein as a UTP:□-D-glucose-1-phosphate uridylyltransferase activity which catalyzes the conversion of glucose-1-phosphate in the presence of UTP to diphosphate and UDP-glucose. For purposes of the present invention UDP-glucose pyrophosphorylase activity is determined according to the procedure described by Kamogawa et al., 1965, *J. Biochem. (Tokyo)* 57: 758-765 or Hansen et al., 1966, *Method Enzymol.* 8: 248-253. One unit of UDP-glucose pyrophosphorylase activity is defined as 1.0 μmole of UDP-glucose produced per minute at 25° C., pH 7.

The term "UDP-N-acetylglucosamine pyrophosphorylase activity" is defined herein as a UTP:N-acetyl-alpha-D-glucoamine-1-phosphate uridylyltransferase activity which catalyzes the conversion of N-acetyl-alpha-D-glucosamine-1-phosphate in the presence of UTP to diphosphate and UDP-N-acetyl-alpha-D-glucoamine. For purposes of the present invention, UDP-N-acetylglucosamine pyrophosphorylase activity is determined according to the procedure described by Mangin-Lecreux et al., 1994, *J. Bacteriology* 176: 5788-5795. One unit of UDP-N-acetylglucosamine pyrophosphorylase activity is defined as 1.0 mmole of UDP-N-acetyl-alpha-D-glucoamine produced per minute at 25° C., pH 7.

The term "isolated nucleic acid sequence" as used herein refers to a nucleic acid sequence which is essentially free of other nucleic acid sequences, e.g., at least about 20% pure, preferably at least about 40% pure, more preferably at least about 60% pure, even more preferably at least about 80% pure, and most preferably at least about 90% pure as determined by agarose electrophoresis. For example, an isolated nucleic acid sequence can be obtained by standard cloning procedures used in genetic engineering to relocate the nucleic acid sequence from its natural location to a different site where it will be reproduced. The cloning procedures may involve excision and isolation of a desired nucleic acid fragment comprising the nucleic acid sequence encoding the polypeptide, insertion of the fragment into a vector molecule, and incorporation of the recombinant vector into a host cell where multiple copies or clones of the nucleic acid sequence will be replicated. The nucleic acid sequence may be of genomic, cDNA, RNA, semisynthetic, synthetic origin, or any combinations thereof.

In a first embodiment, the present invention relates to isolated nucleic acid sequences encoding polypeptides having an amino acid sequence which has a degree of identity to SEQ ID NO: 41 of at least about 75%, preferably at least about 80%, more preferably at least about 85%, even more preferably at least about 90%, most preferably at least about 95%, and even most preferably at least about 97%, which have UDP-glucose 6-dehydrogenase activity (hereinafter "homologous polypeptides"). In a preferred embodiment, the homologous polypeptides have an amino acid sequence which differs by five amino acids, preferably by four amino

acids, more preferably by three amino acids, even more preferably by two amino acids, and most preferably by one amino acid from SEQ ID NO: 41.

In another first embodiment, the present invention relates to isolated nucleic acid sequences encoding polypeptides having an amino acid sequence which has a degree of identity to SEQ ID NO: 43 of at least about 90%, preferably at least about 95%, and more preferably at least about 97%, which have UDP-glucose pyrophosphorylase activity (hereinafter "homologous polypeptides"). In a preferred embodiment, the homologous polypeptides have an amino acid sequence which differs by five amino acids, preferably by four amino acids, more preferably by three amino acids, even more preferably by two amino acids, and most preferably by one amino acid from SEQ ID NO: 43.

In another first embodiment, the present invention relates to isolated nucleic acid sequences encoding polypeptides having an amino acid sequence which has a degree of identity to SEQ ID NO: 45 of at least about 75%, preferably at least about 80%, more preferably at least about 85%, even more preferably at least about 90%, most preferably at least about 95%, and even most preferably at least about 97%, which have UDP-N-acetylglucosamine pyrophosphorylase activity (hereinafter "homologous polypeptides"). In a preferred embodiment, the homologous polypeptides have an amino acid sequence which differs by five amino acids, preferably by four amino acids, more preferably by three amino acids, even more preferably by two amino acids, and most preferably by one amino acid from SEQ ID NO: 45.

For purposes of the present invention, the degree of identity between two amino acid sequences is determined by the Clustal method (Higgins, 1989, *CABIOS* 5: 151-153) using the Vector NTI AlignX software package (Informax Inc., Bethesda, Md.) with the following defaults: pairwise alignment, gap opening penalty of 10, gap extension penalty of 0.1, and score matrix: blosum62mt2.

Preferably, the nucleic acid sequences of the present invention encode polypeptides that comprise the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45; or an allelic variant thereof; or a fragment thereof that has UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity, respectively. In a more preferred embodiment, the nucleic acid sequence of the present invention encodes a polypeptide that comprises the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45. In another preferred embodiment, the nucleic acid sequence of the present invention encodes a polypeptide that consists of the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45; or an allelic variant thereof; or a fragment thereof, wherein the polypeptide fragment has UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity, respectively. In another preferred embodiment, the nucleic acid sequence of the present invention encodes a polypeptide that consists of the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45.

The present invention also encompasses nucleic acid sequences which encode a polypeptide having the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45, which differ from SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44 bp virtue of the degeneracy of the genetic code. The present invention also relates to subsequences of SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44 which encode fragments of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45, respectively, which have UDP-glucose 6-de-

hydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity, respectively.

A subsequence of SEQ ID NO: 40 is a nucleic acid sequence encompassed by SEQ ID NO: 40 except that one or more nucleotides from the 5' and/or 3' end have been deleted. Preferably, a subsequence contains at least 1020 nucleotides, more preferably at least 1080 nucleotides, and most preferably at least 1140 nucleotides. A fragment of SEQ ID NO: 41 is a polypeptide having one or more amino acids deleted from the amino and/or carboxy terminus of this amino acid sequence. Preferably, a fragment contains at least 340 amino acid residues, more preferably at least 360 amino acid residues, and most preferably at least 380 amino acid residues.

A subsequence of SEQ ID NO: 42 is a nucleic acid sequence encompassed by SEQ ID NO: 42 except that one or more nucleotides from the 5' and/or 3' end have been deleted. Preferably, a subsequence contains at least 765 nucleotides, more preferably at least 810 nucleotides, and most preferably at least 855 nucleotides. A fragment of SEQ ID NO: 43 is a polypeptide having one or more amino acids deleted from the amino and/or carboxy terminus of this amino acid sequence. Preferably, a fragment contains at least 255 amino acid residues, more preferably at least 270 amino acid residues, and most preferably at least 285 amino acid residues.

A subsequence of SEQ ID NO: 44 is a nucleic acid sequence encompassed by SEQ ID NO: 44 except that one or more nucleotides from the 5' and/or 3' end have been deleted. Preferably, a subsequence contains at least 1110 nucleotides, more preferably at least 1200 nucleotides, and most preferably at least 1290 nucleotides. A fragment of SEQ ID NO: 45 is a polypeptide having one or more amino acids deleted from the amino and/or carboxy terminus of this amino acid sequence. Preferably, a fragment contains at least 370 amino acid residues, more preferably at least 400 amino acid residues, and most preferably at least 430 amino acid residues.

An allelic variant denotes any of two or more alternative forms of a gene occupying the same chromosomal locus. Allelic variation arises naturally through mutation, and may result in polymorphism within populations. Gene mutations can be silent (no change in the encoded polypeptide) or may encode polypeptides having altered amino acid sequences. The allelic variant of a polypeptide is a polypeptide encoded by an allelic variant of a gene.

In a second embodiment, the present invention relates to isolated nucleic acid sequences which have a degree of homology to SEQ ID NO: 40 of at least about 75%, preferably at least about 80%, more preferably at least about 85%, even more preferably at least about 90%, most preferably at least about 95%, and even most preferably at least about 97%.

In another second embodiment, the present invention relates to isolated nucleic acid sequences which have a degree of homology to SEQ ID NO: 42 of at least about 90%, preferably at least about 95%, and more preferably at least about 97%.

In another second embodiment, the present invention relates to isolated nucleic acid sequences which have a degree of homology to SEQ ID NO: 44 of at least about 75%, preferably at least about 80%, more preferably at least about 85%, even more preferably at least about 90%, most preferably at least about 95%, and even most preferably at least about 97%.

For purposes of the present invention, the degree of homology between two nucleic acid sequences is determined by the Vector NTI AlignX software package (Informax Inc., Bethesda, Md.) using the following defaults: pairwise alignment, gap opening penalty of 15, gap extension penalty of 6.6, and score matrix: swgapdnamt.

In a third embodiment, the present invention relates to isolated nucleic acid sequences encoding polypeptides having UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity, which hybridize under very low stringency conditions, preferably low stringency conditions, more preferably medium stringency conditions, more preferably medium-high stringency conditions, even more preferably high stringency conditions, and most preferably very high stringency conditions with (i) the nucleic acid sequence of SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44, (ii) the cDNA sequence contained in SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44, or (iii) a complementary strand of (i) or (ii) (J. Sambrook, E. F. Fritsch, and T. Maniatus, 1989, *Molecular Cloning, A Laboratory Manual*, 2d edition, Cold Spring Harbor, N.Y.). The subsequence of SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44 may be at least 100 nucleotides or preferably at least 200 nucleotides. Moreover, the respective subsequence may encode a polypeptide fragment which has UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity.

The nucleic acid sequence of SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44, or subsequences thereof, as well as the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45, or a fragment thereof, may be used to design nucleic acid probes to identify and clone DNA encoding polypeptides having UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity, respectively, from strains of different genera or species according to methods well known in the art. In particular, such probes can be used for hybridization with the genomic or cDNA of the genus or species of interest, following standard Southern blotting procedures, in order to identify and isolate the corresponding gene therein. Such probes can be considerably shorter than the entire sequence, but should be at least 15, preferably at least 25, and more preferably at least 35 nucleotides in length. Longer probes can also be used. Both DNA and RNA probes can be used. The probes are typically labeled for detecting the corresponding gene (for example, with ³²P, ³H, ³⁵S, biotin, or avidin). Such probes are encompassed by the present invention.

Thus, a genomic DNA or cDNA library prepared from such other organisms may be screened for DNA which hybridizes with the probes described above and which encodes a polypeptide having UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity. Genomic or other DNA from such other organisms may be separated by agarose or polyacrylamide gel electrophoresis, or other separation techniques. DNA from the libraries or the separated DNA may be transferred to and immobilized on nitrocellulose or other suitable carrier material. In order to identify a clone or DNA which is homologous with SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44, or a subsequence thereof, the carrier material is used in a Southern blot. For purposes of the present invention, hybridization indicates that the nucleic acid sequence hybridizes to a labeled nucleic acid probe corresponding to the nucleic acid sequence shown in SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44, its complementary strand, or a subsequence thereof, under very low to very high stringency conditions. Molecules to which the nucleic acid probe hybridizes under these conditions are detected using X-ray film.

In a preferred embodiment, the nucleic acid probe is a nucleic acid sequence which encodes the polypeptide of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45; or a subsequence thereof. In another preferred embodiment, the nucleic acid probe is SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44. In another preferred embodiment, the nucleic acid probe is the nucleic acid sequence contained in plasmid pMRT106 which is contained in *Escherichia coli* NRRL B-30536, wherein the nucleic acid sequence encodes polypeptides having UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, and UDP-N-acetylglucosamine pyrophosphorylase activity.

For long probes of at least 100 nucleotides in length, very low to very high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and either 25% formamide for very low and low stringencies, 35% formamide for medium and medium-high stringencies, or 50% formamide for high and very high stringencies, following standard Southern blotting procedures.

For long probes of at least 100 nucleotides in length, the carrier material is finally washed three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 45° C. (very low stringency), more preferably at least at 50° C. (low stringency), more preferably at least at 55° C. (medium stringency), more preferably at least at 60° C. (medium-high stringency), even more preferably at least at 65° C. (high stringency), and most preferably at least at 70° C. (very high stringency).

For short probes which are about 15 nucleotides to about 70 nucleotides in length, stringency conditions are defined as prehybridization, hybridization, and washing post-hybridization at 5° C. to 10° C. below the calculated T_m , using the calculation according to Bolton and McCarthy (1962, *Proceedings of the National Academy of Sciences USA* 48:1390) in 0.9 M NaCl, 0.09 M Tris-HCl pH 7.6, 6 mM EDTA, 0.5% NP-40, 1×Denhardt's solution, 1 mM sodium pyrophosphate, 1 mM sodium monobasic phosphate, 0.1 mM ATP, and 0.2 mg of yeast RNA per ml following standard Southern blotting procedures.

For short probes which are about 15 nucleotides to about 70 nucleotides in length, the carrier material is washed once in 6×SSC plus 0.1% SDS for 15 minutes and twice each for 15 minutes using 6×SSC at 5° C. to 10° C. below the calculated T_m .

In a fourth embodiment, the present invention relates to isolated nucleic acid sequences which encode variants of the polypeptide having an amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45 comprising a substitution, deletion, and/or insertion of one or more amino acids.

The amino acid sequences of the variant polypeptides may differ from the amino acid sequence of SEQ ID NO: 41, SEQ ID NO: 43, or SEQ ID NO: 45, by an insertion or deletion of one or more amino acid residues and/or the substitution of one or more amino acid residues by different amino acid residues. Preferably, amino acid changes are of a minor nature, that is conservative amino acid substitutions that do not significantly affect the folding and/or activity of the protein; small deletions, typically of one to about 30 amino acids; small amino- or carboxyl-terminal extensions, such as an amino-terminal methionine residue; a small linker peptide of up to about 20-25 residues; or a small extension that facilitates purification by changing net charge or another function, such as a poly-histidine tract, an antigenic epitope or a binding domain.

Examples of conservative substitutions are within the group of basic amino acids (arginine, lysine and histidine), acidic amino acids (glutamic acid and aspartic acid), polar

amino acids (glutamine and asparagine), hydrophobic amino acids (leucine, isoleucine and valine), aromatic amino acids (phenylalanine, tryptophan and tyrosine), and small amino acids (glycine, alanine, serine, threonine and methionine).

Amino acid substitutions which do not generally alter the specific activity are known in the art and are described, for example, by H. Neurath and R. L. Hill, 1979, *In, The Proteins*, Academic Press, New York. The most commonly occurring exchanges are Ala/Ser, Val/Ile, Asp/Glu, Thr/Ser, Ala/Gly, Ala/Thr, Ser/Asn, Ala/Val, Ser/Gly, Tyr/Phe, Ala/Pro, Lys/Arg, Asp/Asn, Leu/Ile, Leu/Val, Ala/Glu, and Asp/Gly as well as these in reverse.

Modification of a nucleic acid sequence of the present invention may be necessary for the synthesis of polypeptides substantially similar to the polypeptide. The term "substantially similar" to the polypeptide refers to non-naturally occurring forms of the polypeptide. These polypeptides may differ in some engineered way from the polypeptide isolated from its native source, e.g., variants that differ in specific activity, thermostability, pH optimum, or the like. The variant sequence may be constructed on the basis of the nucleic acid sequence presented as the polypeptide encoding part of SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44, e.g., a subsequence thereof, and/or by introduction of nucleotide substitutions which do not give rise to another amino acid sequence of the polypeptide encoded by the nucleic acid sequence, but which corresponds to the codon usage of the host organism intended for production of the enzyme, or by introduction of nucleotide substitutions which may give rise to a different amino acid sequence. For a general description of nucleotide substitution, see, e.g., Ford et al., 1991, *Protein Expression and Purification* 2: 95-107.

It will be apparent to those skilled in the art that such substitutions can be made outside the regions critical to the function of the molecule and still result in an active polypeptide. Amino acid residues essential to the activity of the polypeptide encoded by the isolated nucleic acid sequence of the invention, and therefore preferably not subject to substitution, may be identified according to procedures known in the art, such as site-directed mutagenesis or alanine-scanning mutagenesis (see, e.g., Cunningham and Wells, 1989, *Science* 244: 1081-1085). In the latter technique, mutations are introduced at every positively charged residue in the molecule, and the resultant mutant molecules are tested for enzyme activity to identify amino acid residues that are critical to the activity of the molecule. Sites of substrate-enzyme interaction can also be determined by analysis of the three-dimensional structure as determined by such techniques as nuclear magnetic resonance analysis, crystallography or photoaffinity labelling (see, e.g., de Vos et al., 1992, *Science* 255: 306-312; Smith et al., 1992, *Journal of Molecular Biology* 224: 899-904; Wlodaver et al., 1992, *FEBS Letters* 309: 59-64).

The polypeptides encoded by the isolated nucleic acid sequences of the present invention have at least 20%, preferably at least 40%, more preferably at least 60%, even more preferably at least 80%, even more preferably at least 90%, and most preferably at least 100% of the UDP-glucose 6-dehydrogenase activity of the polypeptide of SEQ ID NO: 41, the UDP-glucose pyrophosphorylase activity of the polypeptide of SEQ ID NO: 43, or the UDP-N-acetylglucosamine pyrophosphorylase activity of the polypeptide of SEQ ID NO: 45.

The nucleic acid sequences of the present invention may be obtained from microorganisms of any genus. For purposes of the present invention, the term "obtained from" as used herein in connection with a given source shall mean that the polypeptide encoded by the nucleic acid sequence is pro-

duced by the source or by a cell in which the nucleic acid sequence from the source has been inserted. In a preferred embodiment, the polypeptide encoded by a nucleic acid sequence of the present invention is secreted extracellularly.

The nucleic acid sequences may be obtained from a bacterial source. For example, these polypeptides may be obtained from a gram positive bacterium such as a *Bacillus* strain, e.g., *Bacillus agaradherens*, *Bacillus alkalophilus*, *Bacillus amyloliquefaciens*, *Bacillus brevis*, *Bacillus circulans*, *Bacillus clausii*, *Bacillus coagulans*, *Bacillus lautus*, *Bacillus lentus*, *Bacillus licheniformis*, *Bacillus megaterium*, *Bacillus stearothermophilus*, *Bacillus subtilis*, or *Bacillus thuringiensis*; or a *Streptomyces* strain, e.g., *Streptomyces lividans* or *Streptomyces murinus*; or from a gram negative bacterium, e.g., *E. coli* or *Pseudomonas* sp.

In a preferred embodiment, the nucleic acid sequences are obtained from a *Streptococcus* or *Pasteurella* strain.

In a more preferred embodiment, the nucleic acid sequences are obtained from a *Streptococcus equisimilis*, *Streptococcus pyogenes*, *Streptococcus uberis*, or *Streptococcus equi* subs. *zooepidemicus* strain, or a *Pasteurella multocida* strain.

In a most preferred embodiment, the nucleic acid sequences are obtained from *Streptococcus equisimilis*, e.g., the nucleic acid sequence set forth in SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44. In another most preferred embodiment, the nucleic acid sequence is the sequence contained in plasmid pMRT106 which is contained in *Escherichia coli* NRRL B-30536. In further most preferred embodiment, the nucleic acid sequence is SEQ ID NO: 40, SEQ ID NO: 42, or SEQ ID NO: 44.

Strains of these species are readily accessible to the public in a number of culture collections, such as the American Type Culture Collection (ATCC), Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH (DSM), Centraalbureau Voor Schimmelcultures (CBS), and Agricultural Research Service Patent Culture Collection, Northern Regional Research Center (NRRL).

Furthermore, such nucleic acid sequences may be identified and obtained from other sources including microorganisms isolated from nature (e.g., soil, composts, water, etc.) using the above-mentioned probes. Techniques for isolating microorganisms from natural habitats are well known in the art. The nucleic acid sequence may then be derived by similarly screening a genomic or cDNA library of another microorganism. Once a nucleic acid sequence encoding a polypeptide has been detected with the probe(s), the sequence may be isolated or cloned by utilizing techniques which are known to those of ordinary skill in the art (see, e.g., Sambrook et al., 1989, supra).

The present invention also relates to mutant nucleic acid sequences comprising at least one mutation in the polypeptide coding sequence of SEQ ID NO: 40, SEQ ID NO: 42, and SEQ ID NO: 44, in which the mutant nucleic acid sequence encodes a polypeptide which consists of SEQ ID NO: 42, SEQ ID NO: 43, and SEQ ID NO: 45, respectively.

The techniques used to isolate or clone a nucleic acid sequence encoding a polypeptide are known in the art and include isolation from genomic DNA, preparation from cDNA, or a combination thereof. The cloning of the nucleic acid sequences of the present invention from such genomic DNA can be effected, e.g., by using the well known polymerase chain reaction (PCR) or antibody screening of expression libraries to detect cloned DNA fragments with shared structural features. See, e.g., Innis et al., 1990, *PCR: A Guide to Methods and Application*, Academic Press, New York. Other nucleic acid amplification procedures such as ligase

chain reaction (LCR), ligated activated transcription (LAT) and nucleic acid sequence-based amplification (NASBA) may be used. The nucleic acid sequence may be cloned from a strain of *Streptococcus*, or another or related organism and thus, for example, may be an allelic or species variant of the polypeptide encoding region of the nucleic acid sequence.

The present invention also relates to nucleic acid constructs comprising a nucleic acid sequence of the present invention operably linked to one or more control sequences which direct the expression of the coding sequence in a suitable host cell under conditions compatible with the control sequences.

The present invention also relates to recombinant expression vectors comprising a nucleic acid sequence of the present invention, a promoter, and transcriptional and translational stop signals.

The present invention also relates to recombinant host cells, comprising a nucleic acid sequence of the invention, which are advantageously used in the recombinant production of the polypeptides.

The present invention also relates to methods for producing a polypeptide having UDP-N-acetylglucosamine pyrophosphorylase activity comprising (a) cultivating a host cell under conditions suitable for production of the polypeptide; and (b) recovering the polypeptide.

In the production methods of the present invention, the cells are cultivated in a nutrient medium suitable for production of the polypeptide using methods known in the art. For example, the cell may be cultivated by shake flask cultivation, and small-scale or large-scale fermentation (including continuous, batch, fed-batch, or solid state fermentations) in laboratory or industrial fermentors performed in a suitable medium and under conditions allowing the polypeptide to be expressed and/or isolated. The cultivation takes place in a suitable nutrient medium comprising carbon and nitrogen sources and inorganic salts, using procedures known in the art. Suitable media are available from commercial suppliers or may be prepared according to published compositions (e.g., in catalogues of the American Type Culture Collection). If the polypeptide is secreted into the nutrient medium, the polypeptide can be recovered directly from the medium. If the polypeptide is not secreted, it can be recovered from cell lysates.

The polypeptides may be detected using methods known in the art that are specific for the polypeptides. These detection methods may include use of specific antibodies, formation of an enzyme product, or disappearance of an enzyme substrate. For example, an enzyme assay may be used to determine the activity of the polypeptide as described herein.

The resulting polypeptide may be recovered by methods known in the art. For example, the polypeptide may be recovered from the nutrient medium by conventional procedures including, but not limited to, centrifugation, filtration, extraction, spray-drying, evaporation, or precipitation.

The polypeptides may be purified by a variety of procedures known in the art including, but not limited to, chromatography (e.g., ion exchange, affinity, hydrophobic, chromatofocusing, and size exclusion), electrophoretic procedures (e.g., preparative isoelectric focusing), differential solubility (e.g., ammonium sulfate precipitation), SDS-PAGE, or extraction (see, e.g., *Protein Purification*, J.-C. Janson and Lars Ryden, editors, VCH Publishers, New York, 1989).

The present invention further relates to the isolated polypeptides having UDP-glucose 6-dehydrogenase, UDP-glucose pyrophosphorylase, or UDP-N-acetylglucosamine pyrophosphorylase activity encoded by the nucleic acid sequences described above.

The present invention is further described by the following examples which should not be construed as limiting the scope of the invention.

EXAMPLES

Primers and Oligos

All primers and oligos were purchased (MWG Biotech Inc., High Point, N.C.)

Example 1

PCR Amplification and Cloning of the *Streptococcus equisimilis* hasA Gene and the *Bacillus subtilis* tuaD, gtaB, and gcaD genes

The *Streptococcus equisimilis* hyaluronan synthase gene (hasA, accession number AF023876, SEQ ID NOs: 1 [DNA sequence] and 2 [deduced amino acid sequence]) was PCR amplified from plasmid pKKseD (Weigel, 1997, *Journal of Biological Chemistry* 272: 32539-32546) using primers 1 and 2:

Primer 1:

5'-GAGCTCTATAAAAATGAGGAGGGAAC-CGAATGAGAACATTAACCT-3' (SEQ ID NO: 3)

Primer 2:

5'-GTTAACGAATTCAGCTATGTAGGTACCT-TATAATAATTTTTACGTGT-3' (SEQ ID NO: 4)

PCR amplifications were conducted in triplicate in 50 μ l reactions composed of 1 ng of pKKseD DNA, 0.4 μ M each of primers 1 and 2, 200 μ M each of dATP, dCTP, dGTP, and dTTP, 1 \times PCR Buffer II (Applied Biosystems, Inc., Foster City, Calif.) with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase (Applied Biosystems, Inc., Foster City, Calif.). The reactions were performed in a RoboCycler 40 thermocycler (Stratagene, Inc., La Jolla, Calif.) programmed for 1 cycle at 95° C. for 9 minutes; 3 cycles each at 95° C. for 1 minute, 52° C. for 1 minute, and 72° C. for 1 minute; 27 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 5 minutes. The PCR product was visualized using a 0.8% agarose gel with 44 mM Tris Base, 44 mM boric acid, 0.5 mM EDTA buffer (0.5 \times TBE). The expected fragment was approximately 1200 bp.

The 1200 bp PCR fragment was cloned into pCR2.1 using the TA-TOPO Cloning Kit (Stratagene, Inc., La Jolla, Calif.) and transformed into *E. coli* OneShot™ competent cells according to the manufacturers' instructions (Stratagene, Inc., La Jolla, Calif.). Transformants were selected at 37° C. after 16 hours of growth on 2 \times yeast-tryptone (YT) agar plates supplemented with 100 μ g of ampicillin per ml. Plasmid DNA from these transformants was purified using a QIAGEN robot (QIAGEN, Valencia, Calif.) according to the manufacturer's instructions and the DNA sequence of the inserts confirmed by DNA sequencing using M13 (-20) forward and M13 reverse primers (Invitrogen, Inc, Carlsbad, Calif.) and the following internal primers. The plasmid harboring the 1200 bp PCR fragment was designated pCR2.1-sehasA (FIG. 3).

Primer 3:

5'-GTTGACGATGGAAGTGCTGA-3' (SEQ ID NO: 5)

Primer 4:

5'-ATCCGTTACAGGTAATATCC-3' (SEQ ID NO: 6)

Primer 5:

5'-TCCTTTTGTAGCCCTATGGA-3' (SEQ ID NO: 7)

Primer 6:

5'-TCAGCACTTCCATCGTCAAC-3' (SEQ ID NO: 8)

Primer 7:

5'-GGATATTACCTGTAACGGAT-3' (SEQ ID NO: 9)

5 Primer 8:

5'-TCCATAGGGCTACAAAAGGA-3' (SEQ ID NO: 10)

The *Bacillus subtilis* UDP-glucose-6-dehydrogenase gene (tuaD, accession number BG12691, SEQ ID NOs: 11 [DNA sequence] and 12 [deduced amino acid sequence]) was PCR amplified from *Bacillus subtilis* 168 (BGSC 1A1, *Bacillus* Genetic Stock Center, Columbus, Ohio) using primers 9 and 10:

Primer 9:

5'-GGTACCGACTGCGACCATTATAAA-3' (SEQ ID NO: 13)

Primer 10:

5'-GTTAACGAATTCAGCTATGTATCTAGACAGCTTCAACCAAGTAACACT-3' (SEQ ID NO: 14)

PCR amplifications were carried out in triplicate in 30 μ l reactions composed of 50 ng of *Bacillus subtilis* 168 chromosomal DNA, 0.3 μ M each of primers 9 and 10, 200 μ M each of dATP, dCTP, dGTP, and dTTP, 1 \times PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 programmed for 1 cycle at 95° C. for 9 minutes; 5 cycles each at 95° C. for 1 minute, 50° C. for 1 minute, and 72° C. for 1.5 minutes; 32 cycles each at 95° C. for 1 minute, 54° C. for 1 minute, and 72° C. for 1.5 minute; and 1 cycle at 72° C. for 7 minutes. The PCR product was visualized in a 0.8% agarose gel using 0.5 \times TBE buffer. The expected fragment was approximately 1400 bp.

The 1400 bp PCR fragment was cloned into pCR2.1 using the TA-TOPO Cloning Kit and transformed into *E. coli* OneShot™ competent cells according to the manufacturers' instructions. Plasmid DNA was purified using a QIAGEN robot according to the manufacturer's instructions and the DNA sequence of the inserts confirmed by DNA sequencing using M13 (-20) forward and M13 reverse primers and the following internal primers. The plasmid harboring the 1400 bp PCR fragment was designated pCR2.1-tuaD (FIG. 4).

Primer 11:

5'-AGCATCTTAACGGCTACAAA-3' (SEQ ID NO: 15)

Primer 12:

5'-TGTGAGCGAGTCGGCGCAGA-3' (SEQ ID NO: 16)

45 Primer 13:

5'-GGGCGCCCATGTAAAAGCAT-3' (SEQ ID NO: 17)

Primer 14:

5'-TTTGTAGCCGTTAAGATGCT-3' (SEQ ID NO: 18)

Primer 15:

50 5'-TCTGCGCCGACTCGCTCACA-3' (SEQ ID NO: 19)

Primer 16:

5'-ATGCTTTTACATGGGCGCCC-3' (SEQ ID NO: 20)

The *Bacillus subtilis* UTP-glucose-1-phosphate uridylyl-transferase gene (gtaB, accession number BG10402, SEQ ID NOs: 21 [DNA sequence] and 22 [deduced amino acid sequence]) was PCR amplified from *Bacillus subtilis* 168 using primers 17 and 18:

Primer 17: 5'-TCTAGATTTTTCGATCATAAGGAAGGT-3' (SEQ ID NO: 23)

Primer 18: 5'-GTTAACGAATTCAGCTATGTAGGATCCAATGTCCAATAGCCTTTTGT-3' (SEQ ID NO: 24)

PCR amplifications were carried out in triplicate in 30 μ l reactions composed of 50 ng of *Bacillus subtilis* 168 chromosomal DNA, 0.3 μ M each of primers 17 and 18, 200 μ M each of dATP, dCTP, dGTP, and dTTP, 1 \times PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40

programmed for 1 cycle at 95° C. for 9 minutes; 5 cycles each at 95° C. for 1 minute, 50° C. for 1 minute, and 72° C. for 1.5 minutes; 32 cycles each at 95° C. for 1 minute, 54° C. for 1 minute, and 72° C. for 1.5 minute; and 1 cycle at 72° C. for 7 minutes. The PCR product was visualized in a 0.8% agarose-0.5×TBE gel. The expected fragment was approximately 900 bp.

The 900 bp PCR fragment was cloned into pCR2.1 using the TA-TOPO cloning kit and transformed into *E. coli* One-Shot™ competent cells according to the manufacturer's instructions. Plasmid DNA was purified using a QIAGEN robot according to the manufacturer's instructions and the DNA sequence of the inserts confirmed by DNA sequencing using M13 (-20) forward and M13 reverse primers and the following internal primers. The plasmid harboring the 900 bp PCR fragment was designated pCR2.1-gtaB (FIG. 5).

Primer 19:

5'-AAAAAGGCTTCTAACCTGGC-3' (SEQ ID NO: 25)

Primer 20:

5'-AAACCGCCTAAAGGCACAGC-3' (SEQ ID NO: 26)

Primer 21:

5'-GCCAGGTTAGAAGCCTTTTT-3' (SEQ ID NO: 27)

Primer 22:

5'-GCTGTGCCTTTAGGCGGTTT-3' (SEQ ID NO: 28)

The *Bacillus subtilis* UDP-N-acetylglucosamine pyrophosphorylase gene (*gcaD*, accession number BG10113, SEQ ID NOs: 29 [DNA sequence] and 30 [deduced amino acid sequence]) was PCR amplified from *Bacillus subtilis* 168 using primers 23 and 24:

Primer 23: 5'-GGATCCTTTCTATGGATAAAAGGGAT-3' (SEQ ID NO: 31)

Primer 24: 5'-GTTAACAGGATTATTTTTTATGAATATTTTT-3' (SEQ ID NO: 32)

PCR amplifications were carried out in triplicate in 30 µl reactions composed of 50 ng of *Bacillus subtilis* 168 chromosomal DNA, 0.3 µM each of primers 23 and 24, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 programmed for 1 cycle at 95° C. for 9 minutes; 5 cycles each at 95° C. for 1 minute, 50° C. for 1 minute, and 72° C. for 1.5 minutes; 32 cycles each at 95° C. for 1 minute, 54° C. for 1 minute, and 72° C. for 1.5 minute; and 1 cycle at 72° C. for 7 minutes. The PCR product was visualized in a 0.8% agarose-0.5×TBE gel. The expected fragment was approximately 1500 bp.

The 1500 bp PCR fragment was cloned into pCR2.1 using the TA-TOPO cloning kit and transformed into *E. coli* One-Shot™ competent cells according to the manufacturer's instructions. Plasmid DNA was purified using a QIAGEN robot according to the manufacturer's instructions and the DNA sequence of the inserts confirmed by DNA sequencing using M13 (-20) forward and M13 reverse primers and the following internal primers. The plasmid harboring the 900 bp PCR fragment was designated pCR2.1-gcaD (FIG. 6).

Primer 25:

5'-CAGAGACGATGGAACAGATG-3' (SEQ ID NO: 33)

Primer 26:

5'-GGAGTTAATGATAGAGTTGC-3' (SEQ ID NO: 34)

Primer 27:

5'-GAAGATCGGGAATTTGTAG-3' (SEQ ID NO: 35)

Primer 28:

5'-CATCTGTTCCATCGTCTCTG-3' (SEQ ID NO: 36)

Primer 29:

5'-GCAACTCTATCATTA ACTCC-3' (SEQ ID NO: 37)

Primer 30:

5'-CTACAAAATTCCCGATCTTC-3' (SEQ ID NO: 38)

Construction of the hasA/tuaD/gtaB Operon

Plasmids pDG268Δneo-cryIIIAstab/Sav (U.S. Pat. No. 5,955,310) and pCR2.1-tuaD (Example 1, FIG. 4) were digested with KpnI and HpaI. The digestions were resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger vector fragment (approximately 7700 bp) from pDG268Δneo-cryIIIAstab/Sav and the smaller tuaD fragment (approximately 1500 bp) from pCR2.1-tuaD were gel-purified using the QIAquick DNA Extraction kit according to the manufacturer's instructions (QIAGEN, Valencia, Calif.). The two purified fragments were ligated together with T4 DNA ligase according to the manufacturer's instructions (Roche Applied Science; Indianapolis, Ind.) and the ligation mix was transformed into *E. coli* SURE competent cells (Stratagene, Inc., La Jolla, Calif.). Transformants were selected on 2×YT agar plates supplemented with 100 mg of ampicillin per ml.

Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by KpnI plus HpaI digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the presence of an approximately 1500 bp KpnI/HpaI tuaD fragment and was designated pHA1 (FIG. 7).

Plasmids pHA1 and pCR2.1-gtaB (Example 1, FIG. 5) were digested with XbaI and HpaI. The digestions were resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger vector fragment from pHA1 (approximately 9200 bp) and the smaller gtaB fragment (approximately 900 bp) from pCR2.1-gtaB were gel-purified from a 0.8% agarose-0.5×TBE buffer gel using the QIAquick DNA Extraction Kit according to the manufacturer's instructions. These two purified fragments were ligated together with T4 DNA ligase and the ligation mix was used to transform *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 mg of ampicillin per ml at 37° C.

Plasmids were purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by XbaI plus HpaI digestion. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The correct plasmid was identified by the presence of an approximately 900 bp XbaI/HpaI gtaB fragment and was designated pHA2 (FIG. 8).

Plasmids pHA2 and pCR2.1-sehasA (Example 1, FIG. 3) were digested with SacI plus KpnI. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The larger vector fragment (approximately 10000 bp) from pHA2 and the smaller hasA fragment (approximately 1300 bp) from pCR2.1-sehasA were gel-purified from a 0.8% agarose-0.5×TBE buffer gel using the QIAquick DNA Extraction kit according to the manufacturer's instructions. The two purified fragments were ligated together with T4 DNA ligase and the ligation mix was used to transform *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 mg of ampicillin per ml at 37° C. Plasmids were purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by SacI plus KpnI digestion. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The correct plasmid was identified by the presence of an approximately 1300 bp SacI/KpnI hasA fragment and was designated pHA3 (FIG. 9).

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Example 3

Construction of the hasA/tuaD/gtaB/gcaD Operon

Plasmids pHA2 (Example 2, FIG. 8) and pCR2.1-gcaD (Example 1, FIG. 6) were digested with BamHI and HpaI. The digestions were resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger vector fragment (approximately 10,000 bp) from pHA2 and the smaller gcaD fragment (approximately 1,400 bp) from pCR2.1-gcaD were gel-purified from a 0.8% agarose-0.5×TBE buffer gel using the QIAquick DNA Extraction Kit according to the manufacturer's instructions. These two purified fragments were ligated together with T4 DNA ligase and the ligation mix was used to transform *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 mg of ampicillin per ml at 37° C.

Plasmids were purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by XbaI plus HpaI digestion. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The correct plasmid was identified by the presence of an approximately 1400 bp BamHI/HpaI gcaD fragment and was designated pHA4 (FIG. 10).

Plasmids pHA4 and pCR2.1-sehasA (Example 1, FIG. 3) were digested with SacI and KpnI. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The larger vector fragment (approximately 11,000 bp) from pHA4 and the smaller hasA fragment (approximately 1,300 bp) from pCR2.1-sehasA were gel-purified from a 0.8% agarose-0.5×TBE buffer gel using the QIAquick DNA Extraction kit according to the manufacturer's instructions. The two purified fragments were ligated together with T4 DNA ligase and the ligation mix was used to transform *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 mg of ampicillin per ml at 37° C. Plasmids were purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by SacI plus KpnI digestion. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The correct plasmid was identified by the presence of an approximately 1,300 bp SacI/KpnI hasA fragment and was designated pHA5 (FIG. 11).

Example 4

Construction of the hasA/tuaD/gcaD Operon

Plasmids pHA1 (Example 2, FIG. 7) and pCR2.1-gcaD (Example 1, FIG. 6) were digested with BamHI and HpaI. The digestions were resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger vector fragment from pHA1 (approximately 9,200 bp) and the smaller gcaD fragment (approximately 1400 bp) from pCR2.1-gcaD were gel-purified from a 0.8% agarose-0.5×TBE buffer gel using the QIAquick DNA Extraction Kit according to the manufacturer's instructions. These two purified fragments were ligated together with T4 DNA ligase and the ligation mix was used to transform *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml at 37° C.

Plasmids were purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by BamHI plus HpaI digestion. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The

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correct plasmid was identified by the presence of an approximately 1400 bp BamHI/HpaI gtaB fragment and was designated pHA6 (FIG. 12).

Plasmids pHA6 and pCR2.1-sehasA (Example 1, FIG. 3) were digested with SacI plus KpnI. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The larger vector fragment (approximately 10,200 bp) from pHA6 and the smaller hasA fragment (approximately 1,300 bp) from pCR2.1-sehasA were gel-purified from a 0.8% agarose-0.5×TBE buffer gel using the QIAquick DNA Extraction kit according to the manufacturer's instructions. The two purified fragments were ligated together with T4 DNA ligase and the ligation mix was used to transform *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml. Plasmids were purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by SacI plus KpnI digestion. The digestions were resolved on a 0.8% agarose-0.5×TBE buffer gel. The correct plasmid was identified by the presence of an approximately 1300 bp SacI/KpnI hasA fragment and was designated pHA7 (FIG. 13).

Example 5

Construction of *Bacillus subtilis* RB161

Plasmid pDG268MCSΔneo/scBAN/Sav (U.S. Pat. No. 5,955,310) was digested with SacI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions, and finally digested with NotI. The largest plasmid fragment of approximately 6800 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions (QIAGEN, Valencia, Calif.). The recovered vector DNA was then ligated with the DNA insert described below.

Plasmid pHA3 (Example 2, FIG. 9) was digested with SacI. The digested plasmid was then purified as described above, and finally digested with NotI. The smallest plasmid fragment of approximately 3800 bp was gel-purified as described above. The recovered vector and DNA insert were ligated using the Rapid DNA Cloning Kit (Roche Applied Science; Indianapolis, Ind.) according to the manufacturer's instructions. Prior to transformation in *Bacillus subtilis*, the ligation described above was linearized using ScaI to ensure double cross-over integration in the chromosome rather than single cross-over integration in the chromosome. Competent cells of *Bacillus subtilis* 168Δ4 were transformed with the ligation products digested with ScaI. *Bacillus subtilis* 168Δ4 is derived from the *Bacillus subtilis* type strain 168 (BGSC 1A1, *Bacillus* Genetic Stock Center, Columbus, Ohio) and has deletions in the spoIIAC, aprE, nprE, and amyE genes. The deletion of these four genes was performed essentially as described for *Bacillus subtilis* A164Δ5, which is described in detail in U.S. Pat. No. 5,891,701.

Bacillus subtilis chloramphenicol-resistant transformants were selected at 34° C. after 16 hours of growth on Tryptose blood agar base (TBAB) plates supplemented with 5 µg of chloramphenicol per ml. To screen for integration of the plasmid by double cross-over at the amyE locus, *Bacillus subtilis* primary transformants were patched on TBAB plates supplemented with 6 µg of neomycin per ml and on TBAB plates supplemented with 5 µg of chloramphenicol per ml. Integration of the plasmid by double cross-over at the amyE locus does not incorporate the neomycin resistance gene and therefore renders the strain neomycin sensitive. Isolates were

also patched onto minimal plates to visualize whether or not these were producing hyaluronic acid. Hyaluronic acid producing isolates have a “wet” phenotype on minimal plates. Using this plate screen, chloramphenicol resistant and neomycin sensitive “wet” transformants (due to hyaluronic acid production) were isolated at 37° C. Genomic DNA was isolated from the “wet”, chloramphenicol resistant, and neomycin sensitive *Bacillus subtilis* 168Δ4 transformants using a QIAGEN tip-20 column (QIAGEN, Valencia, Calif.) according to the manufacturer’s instructions. PCR amplifications were performed on these transformants using the synthetic oligonucleotides below, which are based on the hasA, tuaD, and gtaB gene sequences, to confirm the presence and integrity of these genes in the operon of the *Bacillus subtilis* transformants.

The amplification reactions (25 μl) were composed of approximately 50 ng of genomic DNA of the *Bacillus subtilis* 168Δ4 transformants, 0.5 μM of each primer, 200 μM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II, 3 mM MgCl₂, and 0.625 units of AmpliTaq Gold™ DNA polymerase. The reactions were incubated in a RoboCycler 40 Temperature Cycler programmed for one cycle at 95° C. for 9 minutes; 30 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 2 minutes; and a final cycle at 72° C. for 7 minutes.

Primers 3 and 8 were used to confirm the presence of the hasA gene, primers 3 and 16 to confirm the presence of the tuaD gene, and primers 3 and 22 to confirm the presence of the gtaB gene. The *Bacillus subtilis* 168Δ4 hasA/tuaD/gtaB integrant was designated *Bacillus subtilis* RB158.

Genomic DNA was isolated from *Bacillus subtilis* RB158 using a QIAGEN tip-20 column according to the manufacturer’s instructions, and was used to transform competent *Bacillus subtilis* A164Δ5 (deleted at the spoIIAC, aprE, nprE, amyE, and srfC genes; see U.S. Pat. No. 5,891,701). Transformants were selected on TBAB plates supplemented with 5 μg of chloramphenicol per ml at 37° C. A *Bacillus subtilis* A164Δ5 hasA/tuaD/gtaB integrant was identified by its “wet” phenotype and designated *Bacillus subtilis* RB161.

Example 6

Construction of *Bacillus subtilis* RB163

Plasmid pDG268MCSΔneo/scBAN/Sav (U.S. Pat. No. 5,955,310) was digested with SacI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer’s instructions, and finally digested with NotI. The largest plasmid fragment of approximately 6,800 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer’s instructions. The recovered vector DNA was then ligated with the DNA insert described below.

Plasmid pHA7 (Example 4, FIG. 13) was digested with SacI. The digested plasmid was then purified as described above, and finally digested with NotI. The smallest plasmid fragment of approximately 4,300 bp was gel-purified as described above. The recovered vector and DNA insert were ligated using the Rapid DNA Cloning Kit according to the manufacturer’s instructions. Prior to transformation in *Bacillus subtilis*, the ligation described above was linearized using ScaI to ensure double cross-over integration in the chromosome rather than single cross-over integration in the chromosome. *Bacillus subtilis* 168Δ4 competent cells were transformed with the ligation digested with the restriction enzyme ScaI.

Bacillus subtilis chloramphenicol-resistant transformants were selected on TBAB plates supplemented with 5 μg of chloramphenicol per ml at 37° C. To screen for integration of the plasmid by double cross-over at the amyE locus, *Bacillus subtilis* primary transformants were patched on TBAB plates supplemented with 6 μg of neomycin per ml and on TBAB plates supplemented with 5 μg of chloramphenicol per ml to isolate chloramphenicol resistant and neomycin sensitive “wet” transformants (due to hyaluronic acid production).

Genomic DNA was isolated from the “wet”, chloramphenicol resistant, and neomycin sensitive *Bacillus subtilis* 168Δ4 transformants using a QIAGEN tip-20 column according to the manufacturer’s instructions. PCR amplifications were performed on these transformants using primers 3, 8, 16, 22 and primer 30 (Example 1) to confirm the presence and integrity of these genes in the operon of the *Bacillus subtilis* transformants. The amplification reactions (25 μl) were composed of approximately 50 ng of genomic DNA of the *Bacillus subtilis* 168Δ4 transformants, 0.5 μM of each primer, 200 μM each of dATP, dCTP, dGTP, and dTTP, 1×PCR buffer, 3 mM MgCl₂, and 0.625 units of AmpliTaq Gold™ DNA polymerase. The reactions were incubated in a RoboCycler 40 Temperature Cycler programmed for one cycle at 95° C. for 9 minutes; 30 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 2 minutes; and a final cycle at 72° C. for 7 minutes.

Primers 3 and 8 were used to confirm the presence of the hasA gene, primers 3 and 16 to confirm the presence of the tuaD gene, primers 3 and 22 to confirm the presence of the gtaB gene, and primers 3 and 30 to confirm the presence of the gcaD gene. The *Bacillus subtilis* 168Δ4 hasA/tuaD/gcaD integrant was designated *Bacillus subtilis* RB160.

Genomic DNA was isolated from *Bacillus subtilis* RB160 using a QIAGEN tip-20 column according to the manufacturer’s instructions, and was used to transform competent *Bacillus subtilis* A164Δ5. Transformants were selected on TBAB plates containing 5 μg of chloramphenicol per ml, and grown at 37° C. for 16 hours. The *Bacillus subtilis* A164Δ5 hasA/tuaD/gcaD integrant was identified by its “wet” phenotype and designated *Bacillus subtilis* RB163.

Example 7

Construction of *Bacillus subtilis* TH-1

The hyaluronan synthase (has) operon was obtained from *Streptococcus equisimilis* using the following procedure. The has operon is composed of the hasA, hasB, hasC, and hasD genes. Approximately 20 μg of *Streptococcus equisimilis* D181 (Kumari and Weigel, 1997, *Journal of Biological Chemistry* 272: 32539-32546) chromosomal DNA was digested with HindIII and resolved on a 0.8% agarose-0.5×TBE gel. DNA in the 3-6 kb range was excised from the gel and purified using the QIAquick DNA Gel Extraction Kit according to the manufacturer’s instructions. The recovered DNA insert was then ligated with the vector DNA described below.

Plasmid pUC18 (2 μg) was digested with HindIII and the 5' protruding ends were dephosphorylated with shrimp alkaline phosphatase according to the manufacturer’s instructions (Roche Applied Science; Indianapolis, Ind.). The dephosphorylated vector and DNA insert were ligated using the Rapid DNA Cloning Kit according to the manufacturer’s instructions. The ligation was used to transform *E. coli* XL10 Gold Kan competent cells (Stratagene, Inc., La Jolla, Calif.). Cells were plated onto Luria broth plates (100 μg/ml ampicillin) and incubated overnight at 37° C. Five plates containing

approximately 500 colonies/plate were probed with oligo 952-55-1, shown below, which is a 54 bp sequence identical to the coding strand near the 3' end of the *Streptococcus equisimilis* D181 hasA gene (nucleotides 1098-1151 with respect to the A residue of the ATG translation start codon).

Primer 31:

5'-GTGTCGGAACATTCATTACATGCTTAAG-CACCCGCTGTCCTTCTTGTATCTCC-3' (SEQ ID NO: 39)

The oligonucleotide probe was DIG-labeled using the DIG Oligonucleotide 3'-end Labeling Kit according to the manufacturer's instructions (Roche Applied Science; Indianapolis, Ind.). Colony hybridization and chemiluminescent detection were performed as described in "THE DIG SYSTEM USER'S GUIDE FOR FILTER HYBRIDIZATION", Boehringer Mannheim GmbH.

Seven colonies were identified that hybridized to the probe. Plasmid DNA from one of these transformants was purified using a QIAGEN robot (QIAGEN, Valencia, Calif.) according to the manufacturer's instructions, digested with HindIII, and resolved on a 0.8% agarose gel using 0.5×TBE buffer. The DNA insert was shown to be approximately 5 kb in size. This plasmid was designated pMRT106 (FIG. 14).

The DNA sequence of the cloned fragment was determined using the EZ::TN™ <TET-1> Insertion Kit according to the manufacturer's instructions (Epicenter Technologies, Madison, Wis.). The sequencing revealed that the cloned DNA insert contained the last 1156 bp of the *Streptococcus equisimilis* hasA gene followed by three other genes designated hasB, hasC, and hasD; presumably all four genes are contained within a single operon and are therefore co-transcribed. The *Streptococcus equisimilis* hasB gene is contained in nucleotides 1411-2613 (SEQ ID NOs: 40 [DNA sequence] and 41 [deduced amino acid sequence]) of the fragment, and *Streptococcus equisimilis* hasC gene in nucleotides 2666-3565 (SEQ ID NOs: 42 [DNA sequence] and 43 [deduced amino acid sequence]) of the fragment, and *Streptococcus equisimilis* hasD gene in nucleotides 3735-5114 (SEQ ID NOs: 44 [DNA sequence] and 45 [deduced amino acid sequence]) of the fragment.

The polypeptides encoded by the *Streptococcus equisimilis* hasB and hasC genes show some homology to those encoded by the hasB and hasC genes, respectively, from the *Streptococcus pyogenes* has operon sequence (Ferretti et al., 2001, *Proc. Natl. Acad. Sci. U.S.A.* 98 (8), 4658-4663). The degree of identity was determined by the Clustal method (Higgins, 1989, *CABIOS* 5: 151-153) using the Vector NTI AlignX software (Informax Inc., Bethesda, Md.) with the following defaults: pairwise alignment, gap opening penalty of 10, gap extension penalty of 0.1, and score matrix: blosum62mt2.

Amino acid sequence comparisons showed that the *Streptococcus equisimilis* HasB protein has 70% identity to the HasB protein from *Streptococcus uberis* (SEQ ID NO: 105); the *Streptococcus equisimilis* HasC protein has 91% identity to the HasC protein from *Streptococcus pyogenes* (SEQ ID NO: 99); and the *Streptococcus equisimilis* HasD protein has 73% identity to the GlnU protein (a putative UDP-N-acetylglucosamine pyrophosphorylase) of *Streptococcus pyogenes* (accession # Q8P286). The *Streptococcus equisimilis* hasD gene encodes a polypeptide that shows 50.7% identity to the UDP-N-acetylglucosamine pyrophosphorylase enzyme encoded by the gcaD gene of *Bacillus subtilis*.

Plasmid pHA5 (Example 3, FIG. 11) was digested with HpaI and BamHI. The digestion was resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger vector fragment (approximately 11,000 bp) was gel-purified using the

QIAquick DNA Extraction Kit according to the manufacturer's instructions. Plasmid pMRT106 was digested with HindIII, the sticky ends were filled in with Klenow fragment, and the DNA was digested with BamHI. The digestion was resolved on a 0.8% agarose gel using 0.5×TBE buffer and the smaller insert fragment (approximately 1000 bp, the last 2/3 of the *Streptococcus equisimilis* hasD gene) was gel-purified using the QIAquick DNA Extraction kit according to the manufacturer's instructions.

The two purified fragments were ligated together with T4 DNA ligase and the ligation mix was transformed into *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml at 37° C.

Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by BamHI plus NotI digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the presence of an approximately 1,100 bp BamHI NotI hasD fragment and was designated pHA8 (FIG. 15). This plasmid was digested with HindIII and ligated together with T4 DNA ligase and the ligation mix was transformed into *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml. Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by HindIII digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the presence of a single band of approximately 9,700 bp and was designated pHA9 (FIG. 16).

Plasmid pHA9 was digested with SacI and NotI. The digestion was resolved on a 0.8% agarose gel using 0.5×TBE buffer and the smaller fragment of approximately 2,500 bp was gel-purified using the QIAquick DNA Extraction kit according to the manufacturer's instructions. Plasmid pDG268MCSΔneo/scBAN/Sav (U.S. Pat. No. 5,955,310) was digested with SacI and NotI. The digestion was resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger vector fragment of approximately 6,800 bp was gel-purified using the QIAquick DNA Extraction kit according to the manufacturer's instructions. The two purified fragments were ligated together with T4 DNA ligase and the ligation mix was transformed into *E. coli* SURE competent cells (Stratagene, Inc., La Jolla, Calif.). Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml.

Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by Sall plus HindIII digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the presence of an approximately 1600 bp Sall/HindIII fragment and was designated pHA10 (FIG. 17).

Plasmid pHA10 was digested with HindIII and BamHI. The digestion was resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger vector fragment (approximately 8100 bp) was gel-purified using the QIAquick DNA Extraction kit according to the manufacturer's instructions. Plasmid pMRT106 was digested with HindIII and BamHI. The digestion was resolved on a 0.8% agarose gel using 0.5×TBE buffer and the larger insert fragment of approximately 4,100 bp was gel-purified using the QIAquick DNA Extraction kit according to the manufacturer's instructions. The two purified fragments were ligated together with T4 DNA ligase and the ligation mix was used to transform *Bacillus subtilis* 168Δ4. Transformants were selected on TBAB agar plates supplemented with 5 µg of chloramphenicol per ml at 37° C. Approximately 100 transformants were patched onto TBAB supplemented with chloramphenicol (5 µg/ml)

and TBAB supplemented with neomycin (10 µg/ml) to score chloramphenicol resistant, neomycin sensitive colonies; this phenotype is indicative of a double crossover into the amyE locus. A few such colonies were identified, all of which exhibited a “wet” phenotype indicating that hyaluronic acid was being produced. One colony was chosen and designated *Bacillus subtilis* 168Δ4::scBAN/se hasA/hasB/hasC/hasD.

Genomic DNA was isolated from *Bacillus subtilis* 168Δ4::scBAN/se hasA/hasB/hasC/hasD using a QIAGEN tip-20 column according to the manufacturer’s instructions, and used to transform competent *Bacillus subtilis* A164Δ5. Transformants were selected on TBAB plates containing 5 µg of chloramphenicol per ml, and grown at 37° C. for 16 hours. The *Bacillus subtilis* A164Δ5 hasA/hasB/hasC/hasD integrant was identified by its “wet” phenotype and designated *Bacillus subtilis* TH-1.

Example 8

Construction of *Bacillus subtilis* RB184

The hasA gene from *Streptococcus equisimilis* (Example 1) and tuaD gene (a *Bacillus subtilis* hasB homologue) (Example 1) were cloned to be under the control of a short “consensus” amyQ (scBAN) promoter (U.S. Pat. No. 5,955,310).

Plasmid pDG268MCSΔneo/scBAN/Sav (U.S. Pat. No. 5,955,310) was digested with SacI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer’s instructions, and finally digested with NotI. The largest plasmid fragment of approximately 6,800 bp was gel-purified from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Gel Extraction Kit according to the manufacturer’s instructions. The recovered vector DNA was then ligated with the DNA insert described below.

Plasmid pHA5 (Example 3, FIG. 11) was digested with HpaI. The digested plasmid was then purified as described above, and finally digested with XbaI. The double-digested plasmid was then blunted by first inactivating XbaI at 85° C. for 30 minutes. Blunting was performed by adding 0.5 µl of 10 mM each dNTPs, 1 µl of 1 U/µl T4 DNA polymerase (Roche Applied Science; Indianapolis, Ind.) and incubating at 11° C. for 10 minutes. Finally the polymerase was inactivated by incubating the reaction at 75° C. for 10 minutes. The largest plasmid fragment of approximately 11,000 bp was then gel-purified as described above and religated using the Rapid DNA Cloning Kit according to the manufacturer’s instructions. The ligation mix was transformed into *E. coli* SURE competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml at 37° C. Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer’s instructions and analyzed by ScaI digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the presence of an approximately 11 kb fragment and was designated pRB157 (FIG. 18).

pRB157 was digested with SacI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer’s instructions, and finally digested with NotI. The smallest plasmid fragment of approximately 2,632 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer’s instructions. The recovered DNA insert was then ligated with the vector DNA described above.

Prior to transformation in *Bacillus subtilis*, the ligation described above was linearized using ScaI to ensure double cross-over integration in the chromosome rather than single

cross-over integration in the chromosome. *Bacillus subtilis* 168Δ4 competent cells were transformed with the ligation digested with the restriction enzyme ScaI.

Bacillus subtilis chloramphenicol-resistant transformants were selected on TBAB plates supplemented with 5 µg of chloramphenicol per ml. To screen for integration of the plasmid by double cross-over at the amyE locus, *Bacillus subtilis* primary transformants were patched on TBAB plates supplemented with 6 µg of neomycin per ml and on TBAB plates supplemented with 5 µg of chloramphenicol per ml to isolate chloramphenicol resistant and neomycin sensitive “wet” transformants (due to hyaluronic acid production).

Genomic DNA was isolated from the “wet”, chloramphenicol resistant, and neomycin sensitive *Bacillus subtilis* 168Δ4 transformants using a QIAGEN tip-20 column according to the manufacturer’s instructions. PCR amplifications were performed on these transformants using primers 3, 8, and 16 (Example 1) to confirm the presence and integrity of hasA and tuaD in the operon of the *Bacillus subtilis* transformants. The amplification reactions (25 µl) were composed of approximately 50 ng of genomic DNA of the *Bacillus subtilis* 168Δ4 transformants, 0.5 µM of each primer, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1×PCR buffer, 3 mM MgCl₂, and 0.625 units of AmpliTaq Gold™ DNA polymerase. The reactions were incubated in a RoboCycler 40 Temperature Cycler programmed for one cycle at 95° C. for 9 minutes; 30 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 2 minutes; and a final cycle at 72° C. for 7 minutes.

Primers 3 and 8 were used to confirm the presence of the hasA gene and primers 3 and 16 to confirm the presence of the tuaD gene. A *Bacillus subtilis* 168Δ4 hasA/tuaD integrant was designated *Bacillus subtilis* RB183.

Bacillus subtilis RB183 genomic DNA was also used to transform competent *Bacillus subtilis* A164Δ5. Transformants were selected on TBAB plates containing 5 µg of chloramphenicol per ml, and grown at 37° C. for 16 hours. The *Bacillus subtilis* A164Δ5 hasA/tuaD integrant was identified by its “wet” phenotype and designated *Bacillus subtilis* RB184.

Example 9

Construction of *Bacillus subtilis* RB187

Bacillus subtilis RB161 was made competent and transformed with the cat deletion plasmid pRB115 (Widner et al., 2000, *Journal of Industrial Microbiology & Biotechnology* 25: 204-212). Selection for direct integration into the chromosome was performed at the non-permissive temperature of 45° C. using erythromycin (5 µg/ml) selection. At this temperature, the pE194 origin of replication is inactive. Cells are able to maintain erythromycin resistance only by integration of the plasmid into the cat gene on the bacterial chromosome. These so-called “integrants” were maintained at 45° C. to ensure growth at this temperature with selection. To allow for loss or “looping out” of the plasmid, which will result in the deletion of most of the cat gene from the chromosome, the integrants were grown in Luria-Bertani (LB) medium without selection at the permissive temperature of 34° C. for many generations. At this temperature the pE194 origin of replication is active and promotes excision of the plasmid from the genome (*Molecular Biological Methods for Bacillus*, edited by C. R. Harwood and S. M. Cutting, 1990, John Wiley and Sons Ltd.).

The cells were then plated on non-selective LB agar plates and colonies which contained deletions in the cat gene and loss of the pE194-based replicon were identified by the fol-

lowing criteria: (1) chloramphenicol sensitivity indicated the presence of the cat deletion; (2) erythromycin sensitivity indicated the absence of the erythromycin resistance gene encoded by the vector pRB115; and (3) PCR confirmed the presence of the cat deletion in the strain of interest. PCR was performed to confirm deletion of the cat gene at the amyE locus by using primers 32 and 33:

Primer 32: 5'-GCGGCCGCGGTACCTGTGTTACACCTGTT-3' (SEQ ID NO: 46)

Primer 33: 5'-GTCAAGCTTAATTCTCATGTTTGA-CAGCTTATCATCGG-3' (SEQ ID NO: 47)

Chromosomal DNA from potential deletants was isolated using the REDextract-N-Amp™ Plant PCR kits (Sigma Chemical Company, St. Louis, Mo.) as follows: Single *Bacillus* colonies were inoculated into 100 µl of Extraction Solution (Sigma Chemical Company, St. Louis, Mo.), incubated at 95° C. for 10 minutes, and then diluted with an equal volume of Dilution Solution (Sigma Chemical Company, St. Louis, Mo.). PCR was performed using 4 µl of extracted DNA in conjunction with the REDextract-N-Amp PCR Reaction Mix and the desired primers according to the manufacturer's instructions, with PCR cycling conditions described in Example 5. PCR reaction products were visualized in a 0.8% agarose-0.5×TBE gel. The verified strain was named *Bacillus subtilis* RB187.

Example 10

Construction of *Bacillus subtilis* RB192

Bacillus subtilis RB184 was made unmarked by deleting the chloramphenicol resistance gene (cat gene). This was accomplished using the method described previously in Example 9. The resultant strain was designated *Bacillus subtilis* RB192.

Example 11

Construction of *Bacillus subtilis* RB194

Bacillus subtilis RB194 was constructed by deleting the cypX region of the chromosome of *Bacillus subtilis* RB187 (Example 9). The cypX region includes the cypX gene which encodes a cytochrome P450-like enzyme that is involved in the synthesis of a red pigment during fermentation. In order to delete this region of the chromosome plasmid pMRT086 was constructed.

The region of the chromosome which harbors the cypX-yvmC and yvmB-yvmA operons was PCR amplified from *Bacillus subtilis* BRG-1 as a single fragment using primers 34 and 35. *Bacillus subtilis* BRG1 is essentially a chemically mutagenized isolate of an amylase-producing strain of *Bacillus subtilis* which is based on the *Bacillus subtilis* A164Δ5 genetic background that was described in Example 5. The sequence of this region is identical to the published sequence for the *Bacillus subtilis* 168 type strain.

Primer 34: 5'-CATGGGAGAGACCTTTGG-3' (SEQ ID NO: 48)

Primer 35: 5'-GTCGGTCTTCCATTTGC-3' (SEQ ID NO: 49)

The amplification reactions (50 µl) were composed of 200 ng of *Bacillus subtilis* BRG-1 chromosomal DNA, 0.4 µM each of primers 34 and 35, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1× Expand™ High Fidelity buffer (Roche Applied Science; Indianapolis, Ind.) with 1.5 mM MgCl₂, and 2.6 units of Expand™ High Fidelity PCR System enzyme mix (Roche Applied Science; Indianapolis, Ind.). *Bacillus*

subtilis BRG-1 chromosomal DNA was obtained using a QIAGEN tip-20 column according to the manufacturer's instructions. Amplification reactions were performed in a RoboCycler 40 thermacycler (Stratagene, Inc, La Jolla, Calif.) programmed for 1 cycle at 95° C. for 3 minutes; 10 cycles each at 95° C. for 1 minute, 58° C. for 1 minute, and 68° C. for 4 minutes; 20 cycles each at 95° C. for 1 minute, 58° C. for 1 minute, 68° C. for 4 minutes plus 20 seconds per cycle, followed by 1 cycle at 72° C. for 7 minutes. Reaction products were analyzed by agarose gel electrophoresis using a 0.8% agarose gel using 0.5×TBE buffer.

The resulting fragment comprising the cypX-yvmC and yvmB-yvmA operons was cloned into pCR2.1 using the TA-TOPO Cloning Kit and transformed into *E. coli* OneShot™ cells according to the manufacturer's instructions (Invitrogen, Inc., Carlsbad, Calif.). Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml. Plasmid DNA from several transformants was isolated using QIAGEN tip-20 columns according to the manufacturer's instructions and verified by DNA sequencing with M13 (-20) forward, M13 reverse and primers 36 to 51 shown below. The resulting plasmid was designated pMRT084 (FIG. 19).

Primer 36: 5'-CGACCACTGTATCTTGG-3' (SEQ ID NO: 50)

Primer 37: 5'-GAGATGCCAAACAGTGC-3' (SEQ ID NO: 51)

Primer 38: 5'-CATGTCCATCGTGACG-3' (SEQ ID NO: 52)

Primer 39: 5'-CAGGAGCATTGATAACG-3' (SEQ ID NO: 53)

Primer 40: 5'-CCTTCAGATGTGATCC-3' (SEQ ID NO: 54)

Primer 41: 5'-GTGTTGACGTCAACTGC-3' (SEQ ID NO: 55)

Primer 42: 5'-GTTTCAGCCTTTCCTCTCG-3' (SEQ ID NO: 56)

Primer 43: 5'-GCTACCTTCTTTCTTAGG-3' (SEQ ID NO: 57)

Primer 44: 5'-CGTCAATATGATCTGTGC-3' (SEQ ID NO: 58)

Primer 45: 5'-GGAAAGAAGGTCTGTGC-3' (SEQ ID NO: 59)

Primer 46: 5'-CAGCTATCAGCTGACAG-3' (SEQ ID NO: 60)

Primer 47: 5'-GCTCAGCTATGACATATTCC-3' (SEQ ID NO: 61)

Primer 48: 5'-GATCGTCTTGATTACCG-3' (SEQ ID NO: 62)

Primer 49: 5'-AGCTTTATCGGTGACG-3' (SEQ ID NO: 63)

Primer 50: 5'-TGAGCACGATTGCAGG-3' (SEQ ID NO: 64)

Primer 51: 5'-CATTGCGGAGACATTGC-3' (SEQ ID NO: 65)

Plasmid pMRT084 was digested with BsgI to delete most of the cypX-yvmC and yvmB-yvmA operons, leaving about 500 bases at each end. The digested BsgI DNA was treated with T4 DNA polymerase. Plasmid pECC1 (Youngman et al., 1984, *Plasmid* 12: 1-9) was digested with SmaI. A fragment of approximately 5,100 bp from pMRT084 and a fragment of approximately 1,600 bp fragment from pECC1 were isolated from a 0.8% agarose-0.5×TBE gel using the QIAquick DNA Extraction Kit according to the manufacturer's instructions, ligated together, and transformed into *E. coli* XL1 Blue cells according to the manufacturer's instructions (Stratagene, Inc., La Jolla, Calif.). Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml. Transformants carrying the correct plasmid with most of the cypX-yvmC and yvmB-yvmA operons deleted were identi-

fied by PCR amplification using primers 52 and 53. PCR amplification was conducted in 50 µl reactions composed of 1 ng of plasmid DNA, 0.4 µM of each primer, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 thermocycler programmed for 1 cycle at 95° C. for 10 minutes; 25 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 7 minutes. The PCR product was visualized using a 0.8% agarose-0.5×TBE gel.

This construct was designated pMRT086 (FIG. 20).
Primer 52: 5'-TAGACAATTGGAAGAGAAAAGAGATA-3' (SEQ ID NO: 66)

Primer 53: 5'-CCGTCGCTATTGTAACCAAGT-3' (SEQ ID NO: 67)

Plasmid pMRT086 was linearized with *ScaI* and transformed into *Bacillus subtilis* RB128 competent cells in the presence of 0.2 µg of chloramphenicol per ml. Transformants were selected on TBAB plates containing 5 µg of chloramphenicol per ml after incubation at 37° C. for 16 hours. Chromosomal DNA was prepared from several transformants using a QIAGEN tip-20 column according to the manufacturer's instructions. Chloramphenicol resistant colonies were screened by PCR for deletion of the *cypX-yvmC* and *yvmB-yvmA* operons via PCR using primers 36 and 52, 36 and 53, 37 and 52, and 37 and 53. PCR amplification was conducted in 50 µl reactions composed of 50 ng of chromosomal DNA, 0.4 µM of each primer, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 thermocycler programmed for 1 cycle at 95° C. for 10 minutes; 25 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 7 minutes. The PCR products were visualized using a 0.8% agarose-0.5×TBE gel. The resulting *Bacillus subtilis* RB128 *cypX-yvmC* and *yvmB-yvmA* deleted strain was designated *Bacillus subtilis* MaTa17.

Competent cells of *Bacillus subtilis* RB187 (Example 9) were transformed with genomic DNA from *Bacillus subtilis* MaTa17. Genomic DNA was obtained from this strain using a QIAGEN tip-20 column according to the manufacturer's instructions. *Bacillus subtilis* chloramphenicol resistant transformants were selected on TBAB plates supplemented with 5 µg of chloramphenicol per ml at 37° C. Primary transformants were streaked for single colony isolations on TBAB plates containing 5 µg of chloramphenicol per ml at 37° C. The resulting *cypX-yvmC* and *yvmB-yvmA* deleted strain was designated *Bacillus subtilis* RB194.

Example 12

Construction of *Bacillus subtilis* RB197

Bacillus subtilis RB197 is very similar to *Bacillus subtilis* RB194, the only difference being that RB197 contains a smaller deletion in the *cypX* region: only a portion of the *cypX* gene is deleted in this strain to generate a *cypX* minus phenotype. In order to accomplish this task a plasmid, pMRT122, was constructed as described below.

Plasmid pCJ791 (FIG. 21) was constructed by digestion of plasmid pSJ2739 (WO 96/23073) with *EcoRI*/*HindIII* and ligation to a fragment containing a deleted form of the *wprA* gene (cell wall serine protease) from *Bacillus subtilis*. The 5' region of *wprA* was amplified using primers 54 and 55 see below, and the 3' region was amplified using primers 56 and 57 shown below from chromosomal DNA obtained from

Bacillus subtilis DN1885 (Diderichsen et al., 1990, *Journal of Bacteriology* 172: 4315-4321). PCR amplification was conducted in 50 µl reactions composed of 1 ng of *Bacillus subtilis* DN1885 chromosomal DNA, 0.4 µM each of primers 39 and 40, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 thermocycler programmed for 1 cycle at 95° C. for 10 minutes; 25 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 7 minutes. The 5' and 3' *wprA* PCR fragments were linked by digestion with *BglIII* followed by ligation, and PCR amplification was performed on the ligation mixture fragments using primers 54 and 57. PCR amplification was conducted in 50 µl reactions composed of 1 ng of the ligated fragment, 0.4 µM of each primer, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 thermocycler programmed for 1 cycle at 95° C. for 10 minutes; 25 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 7 minutes. The PCR product was visualized using a 0.8% agarose-0.5×TBE gel. The resulting PCR fragment was cloned into pSJ2739 as an *EcoRI*/*HindIII* fragment, resulting in plasmid pCJ791 (FIG. 21). Transformants were selected on TBAB-agar plates supplemented with 1 µg of erythromycin and 25 µg of kanamycin per ml after incubation at 28° C. for 24-48 hours. Plasmid DNA from several transformants was isolated using QIAGEN tip-20 columns according to the manufacturer's instructions and verified by PCR amplification with primers 54 and 57 using the conditions above.

Primer 54: 5'-GGAATTCCAAAGCTGCAGCGGCCG-GCGCG-3' (SEQ ID NO: 68)

Primer 55: 5'-GAAGATCTCGTATACTTGGCTTCTG-CAGCTGC-3' (SEQ ID NO: 69)

Primer 56: 5'-GAAGATCTGGTCAACAAGCTGGAAAG-CACTC-3' (SEQ ID NO: 70)

Primer 57: 5'-CCCAAGCTTCGTGACGTACAGCACCGT-TCCGGC-3' (SEQ ID NO: 71)

The amyL upstream sequence and 5' coding region from plasmid pDN1981 (U.S. Pat. No. 5,698,415) were fused together by SOE using the primer pairs 58/59 and 60/61 shown below. The resulting fragment was cloned into vector pCR2.1 to generate plasmid pMRT032 as follows. PCR amplifications were conducted in triplicate in 50 µl reactions composed of 1 ng of pDN1981 DNA, 0.4 µM each of appropriate primers, 200 µM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 thermocycler programmed for 1 cycle at 95° C. for 9 minutes; 3 cycles each at 95° C. for 1 minute, 52° C. for 1 minute, and 72° C. for 1 minute; 27 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 5 minutes. The PCR product was visualized in a 0.8% agarose-0.5×TBE gel. The expected fragments were approximately 530 and 466 bp, respectively. The final SOE fragment was generated using primer pair 59/60 and cloned into pCR2.1 vector using the TA-TOPO Cloning Kit. Transformants were selected on 2×YT agar plates supplemented with 100 µg/ml ampicillin after incubation at 37° C. for 16 hours. Plasmid DNA from several transformants was isolated using QIAGEN tip-20 columns according to the manufacturer's instructions and verified by DNA sequencing with M13 (-20) forward and M13 reverse prim-

ers. The plasmid harboring the amyL upstream sequence/5' coding sequence fusion fragment was designated pMRT032 (FIG. 22).

Primer 58:

5'-CCTTAAGGGCCGAATATTTATACG-GAGCTCCCTGAAACAACAAAAACGGC-3' (SEQ ID NO: 72)

Primer 59: 5'-GGTGTCTCTAGAGCGGCCGCGGT-TGCGGTCAGC-3' (SEQ ID NO: 73)

Primer 60: 5'-GTCCTTCTTGGTACCTGGAAGCAGAGC-3' (SEQ ID NO: 74)

Primer 61: 5'-GTATAAATATTCGGCCCTTAAGGCCAG-TACCATTTTCCC-3' (SEQ ID NO: 75)

Plasmid pNNB194 (pSK⁺/pE194; U.S. Pat. No. 5,958,728) was digested with NsiI and NotI, and plasmid pBEST501 Maya et al. 1989 Nucleic Acids Research 17: 4410) was digested with PstI and NotI. The 5,193 bp vector fragment from pNNB194 and the 1,306 bp fragment bearing the neo gene from pBEST501 were isolated from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions. The isolated fragments were ligated together and used to transform *E. coli* SURE competent cells according to the manufacturer's instructions. Ampicillin-resistant transformants were selected on 2×YT plates supplemented with 100 µg of ampicillin per ml. Plasmid DNA was isolated from one such transformant using the QIAGEN Plasmid Kit (QIAGEN Inc., Valencia, Calif.), and the plasmid was verified by digestion with NsiI and NotI. This plasmid was designated pNNB194neo (FIG. 23).

Plasmid pNNB194neo was digested with SacI/NotI and treated with T4 DNA polymerase and dNTPs to generate blunt ends using standard protocols. Plasmid pPL2419 (U.S. Pat. No. 5,958,728) was digested with Ecl136II. The 6,478 bp vector fragment from pNNB194neo and the 562 bp fragment bearing oriT from pPL2419 were isolated from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions. The gel-purified fragments were ligated together and used to transform *E. coli* SURE cells according to the manufacturer's instructions. Ampicillin-resistant transformants were selected on 2×YT plates supplemented with 100 µg of ampicillin per ml at 37° C. Plasmid DNA was isolated from one such transformant using the QIAGEN Plasmid Kit, and the plasmid was verified by digestion with NsiI, SacI, and BscI. This plasmid was designated pNNB194neo-oriT (FIG. 24).

Plasmid pNNB194neo-oriT was digested with BamHI and treated with T4 DNA polymerase and dNTPs to generate blunt ends using standard protocols. The digested plasmid was gel-purified from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions. The purified plasmid was treated with T4 DNA ligase and used to transform *E. coli* SURE cells according to the manufacturer's instructions. Ampicillin-resistant transformants were selected on 2×YT plates supplemented with 100 µg of ampicillin per ml at 37° C. Plasmid DNA was isolated from one such transformant using the QIAGEN Plasmid Kit, and disruption of the BamHI site was confirmed by digestion with BamHI and ScaI. The resulting plasmid was designated pShV3 (FIG. 25).

Plasmid pShV2.1-amyEΔ (U.S. Pat. No. 5,958,728) was digested with SfiI and NotI, and the 8696 bp vector fragment was gel-purified from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions. In order to insert a BamHI site between the SfiI and NotI sites of pShV2.1-amyEΔ, a synthetic linker

was constructed as follows: primers 62 and 63 were annealed by mixing 50 µM of each, boiling the mixture, and allowing the mixture to cool slowly.

Primer 62: 5'-GGGCCGGATCCGC-3' (SEQ ID NO: 76)

Primer 63: 3'-ATTCCCGGCCTAGGCGCCGG-5' (SEQ ID NO: 77)

The purified pShV2.1-amyEΔ vector and annealed oligonucleotides were ligated together and used to transform *E. coli* SURE competent cells according to the manufacturer's instructions. Chloramphenicol-resistant transformants were selected on LB plates supplemented with 30 µg of chloramphenicol per ml at 37° C. Plasmid DNA was isolated from one such transformant using the QIAGEN Plasmid Kit, and insertion of the BamHI site was confirmed by digestion with BamHI. This plasmid was designated pShV2.1-amyEΔB (FIG. 26).

Plasmids pShV3 and pShV2.1-amyEΔB were digested with Sall/HindIII. A 7033 bp vector fragment from pShV3 and a 1031 bp fragment bearing amyEΔ, from pShV2.1-amyEΔ were gel-purified from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions. The gel-purified fragments were ligated together and used to transform *E. coli* SURE cells according to the manufacturer's instructions. Ampicillin-resistant transformants were selected on 2×YT plates supplemented with 100 µg of ampicillin per ml. Plasmid DNA was isolated from one such transformant using the QIAGEN Plasmid Kit, and the plasmid was verified by digestion with Sall and HindIII. This plasmid was designated pShV3A (FIG. 27).

Plasmid pMRT032 was digested with KpnI/XbaI, filled with Klenow fragment DNA polymerase in the presence of dNTPs, and a fragment of approximately 1000 bp was isolated from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions. This fragment was cloned into plasmid pShV3a digested with EcoRV, and transformed into *E. coli* XL1 Blue cells according to the manufacturer's instructions. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml after incubation at 37° C. for 16 hours. Plasmid DNA from several transformants was isolated using QIAGEN tip-20 columns according to the manufacturer's instructions and verified on a 0.8% agarose-0.5×TBE gel by restriction analysis with SacI/SphI. The resulting plasmid was designated pMRT036 (FIG. 28).

Plasmid pMRT036 was digested with Sall/HindIII, filled with Klenow fragment DNA polymerase in the presence of dNTPs, ligated and transformed into *E. coli* XL1 Blue cells according to the manufacturer's instructions. Transformants were selected on 2×YT-agar plates supplemented with 100 µg/ml ampicillin after incubation at 37° C. for 16 hours. Plasmid DNA from several transformants was isolated using QIAGEN tip-20 columns according to the manufacturer's instructions and verified on a 0.8% agarose-0.5×TBE gel by restriction analysis with SacI/XbaI, PstI and NdeI. The resulting plasmid was designated pMRT037 (FIG. 29).

The scBAN/cryIIIA stabilizer fragment from plasmid pDG268Δneo-cryIIIAstab/Sav (U.S. Pat. No. 5,955,310) was isolated from a 2% agarose-0.5×TBE gel as a SfiI/SacI fragment using a QIAquick DNA Purification Kit according to the manufacturer's instructions, ligated to plasmid pMRT037 digested with SfiI/SacI, and transformed into *E. coli* XL1 Blue cells. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml after incubation at 37° C. for 16 hours. Plasmid DNA from several transformants was isolated using QIAGEN tip-20 columns according to the manufacturer's instructions and verified on a 0.8%

agarose-0.5×TBE gel by restriction analysis with PstI. The resulting plasmid was designated pMRT041 (FIG. 30).

Plasmids pMRT041 and pCJ791 were digested with EcoRI/HindIII. A fragment of approximately 1300 bp from pMRT041 and a fragment of approximately 4500 bp from pCJ791 were isolated from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions, ligated, and transformed into *Bacillus subtilis* 168Δ4 competent cells. Transformants were selected on TBAB-agar plates supplemented with 1 μg of erythromycin and 25 μg of lincomycin per ml after incubation at 30° C. for 24-48 hours. Plasmid DNA from several transformants was isolated using QIAGEN tip-20 columns according to the manufacturer's instructions and verified on a 0.8% agarose-0.5×TBE gel by restriction analysis with SacI and EcoRI/HindIII. The resulting plasmid was designated pMRT064.1 (FIG. 31).

The SacI site at position 2666 in plasmid pMRT064.1 was deleted by SOE using primer pairs 64 and 65, and primer pairs 66 and 67 shown below. PCR amplification was conducted in 50 μl reactions composed of 1 ng of pMRT064.1 DNA, 0.4 μM of each primer, 200 μM each of dATP, dCTP, dGTP, and dTTP, 1×PCR BufferII with 2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 thermocycler programmed for 1 cycle at 95° C. for 10 minutes; 25 cycles each at 95° C. for 1 minute, 52° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 7 minutes. The PCR product was visualized in a 0.8% agarose-0.5×TBE gel. The expected fragments were approximately 400 and 800 bp, respectively. The final fragment for cloning back into pMRT064.1 was amplified using primers 64 and 67. This fragment was cloned into pCR2.1 vector using the TA-TOPO Cloning Kit. Transformants were selected on 2×YT agar plates supplemented with 100 μg/ml ampicillin after incubation at 37° C. for 16 hours. Transformants carrying the correct plasmid were verified by DNA sequencing using M13 forward and reverse primers, and primers 65, 67, and 68. This plasmid was designated pMRT068 (FIG. 32), and was further transformed into *E. coli* DM1 cells (Stratagene, Inc., La Jolla, Calif.) according to the manufacturer's instructions. Transformants were selected on 2×YT agar plates supplemented with 100 μg of ampicillin per ml.

Primer 64: 5'-GGAAATTATCGTGATCAAC-3' (SEQ ID NO: 78)

Primer 65: 5'-GCACGAGCACTGATAAATATG-3' (SEQ ID NO: 79)

Primer 66: 5'-CATATTTATCAGTGCTCGTGC-3' (SEQ ID NO: 80)

Primer 67: 5'-TCGTAGACCTCATATGC-3' (SEQ ID NO: 81)

Primer 68: 5'-GTCGTTAAACCGTGTGC-3' (SEQ ID NO: 82)

The SacI sites at positions 5463 and 6025 in plasmid pMRT064.1 were deleted using PCR amplification with primers 69 and 70, and using the PCR conditions described above. The resulting fragment was cloned into pCR2.1 vector using the TA-TOPO Cloning Kit (Invitrogen, Inc., Carlsbad, Calif.). Transformants were selected on 2×YT-agar plates supplemented with 100 μg of ampicillin per ml after incubation at 37° C. for 16 hours. Transformants carrying the correct plasmid were verified by DNA sequencing using M13 forward and reverse primers. This construct was designated pMRT069 (FIG. 33).

Primer 69: 5'-CTAGAGGATCCCCGGGTACCGTGCTCTGCCTTTTAGTCC-3' (SEQ ID NO: 83)

Primer 70: 5'-GTACATCGAATTCGTGCTCATTATTAATCTGTTTCAGC-3' (SEQ ID NO: 84)

Plasmids pMRT068 and pMRT064.1 were digested with Bdi/AccI. A fragment of approximately 1300 bp from

pMRT068 and a fragment of approximately 3800 bp from pMRT064.1 were isolated from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions, ligated, and transformed into *Bacillus subtilis* 168Δ4 competent cells. Transformants were selected on TBAB-agar plates supplemented with 1 μg of erythromycin and 25 μg of lincomycin per ml after incubation at 30° C. for 24-48 hours. Transformants carrying the correct plasmid were identified on a 0.8% agarose-0.5×TBE gel by restriction analysis with SacI and EcoRI/AvaI. The resulting construct was designated pMRT071 (FIG. 34).

Plasmids pMRT071 and pMRT069 were digested with AvaI/EcoRI. The 578 bp fragment from pMRT069 and the 4510 bp fragment from pMRT071 were isolated from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions, ligated, and transformed into *Bacillus subtilis* 168Δ4 competent cells. Transformants were selected on TBAB-agar plates supplemented with 1 μg of erythromycin and 25 μg of lincomycin per ml after incubation at 30° C. for 24-48 hours. Transformants carrying the correct plasmid were identified on a 0.8% agarose-0.5×TBE gel by restriction analysis with SacI. The resulting construct was designated pMRT074 (FIG. 35).

Plasmid pMRT084 described in Example 11 was digested with SacII/NdeI, treated with T4 DNA polymerase, ligated, and transformed into *E. coli* XL1 Blue cells according to the manufacturer's instructions. Transformants were selected on 2×YT agar plates supplemented with 100 μg of ampicillin per ml after incubation at 37° C. for 16 hours. Transformants carrying the correct plasmid were identified on a 0.8% agarose-0.5×TBE gel by restriction analysis with DraI. The resulting plasmid was named pMRT120 (FIG. 36).

Plasmid pMRT074 was digested with HindIII, treated with Klenow fragment DNA polymerase, and digested with EcoRI. Plasmid pMRT120 was digested with EcoRI/Ecl136II. A fragment of approximately 600 bp from pMRT120 and a fragment of approximately 4300 bp from pMRT074 were isolated from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Purification Kit according to the manufacturer's instructions, ligated, and transformed into *Bacillus subtilis* 168Δ4 competent cells. Transformants were selected on TBAB-agar plates supplemented with 1 μg of erythromycin and 25 μg of lincomycin per ml after incubation at 30° C. for 24-48 hours. Transformants carrying the correct plasmid were identified on a 0.8% agarose-0.5×TBE gel by restriction analysis with SspI. The resulting construct was designated pMRT122 (FIG. 37).

Plasmid pMRT122 was transformed into *Bacillus subtilis* A164Δ5 competent cells. Transformants were selected on TBAB-agar plates supplemented with 1 μg of erythromycin and 25 μg of lincomycin per ml after incubation at 30° C. for 24-48 hours. The plasmid was introduced into the chromosome of *Bacillus subtilis* A164Δ5 via homologous recombination into the *cypX* locus by incubating a freshly streaked plate of *Bacillus subtilis* A164Δ5 (pMRT086) cells at 45° C. for 16 hours and selecting for healthy growing colonies. Genomic DNA was isolated from this strain using a QIAGEN tip-20 column according to the manufacturer's instructions and used to transform *Bacillus subtilis* RB187 (Example 9). Transformants were selected on TBAB plates supplemented with 1 μg of erythromycin and 25 μg of lincomycin per ml after incubation at 45° C. for 16 hours. At this temperature, the pE194 replicon is unable to replicate. Cells are able to maintain erythromycin resistance only by maintaining the plasmid in the bacterial chromosome.

The plasmid was removed from the chromosome via homologous recombination resulting in the deletion of a portion of the *cypX* gene on the chromosome by growing the

transformants in Luria-Bertani (LB) medium without selection at the permissive temperature of 34° C. for many generations. At this temperature the pE194 origin of replication is active and actually promotes the excision of the plasmid from the chromosome (*Molecular Biological Methods for Bacillus*, edited by C. R. Harwood and S. M. Cutting, 1990, John Wiley and Sons Ltd.).

After several generations of outgrowth the cells were plated on non-selective LB agar plates and colonies which had lost the plasmid and were now cypX-deleted and producing hyaluronic acid were identified as follows: (1) cell patches were “wet” when plated on minimal plates indicating production of hyaluronic acid, (2) erythromycin sensitivity indicated loss of the pE194-based plasmid, and (3) PCR confirmed the presence of the 800 bp cypX deletion in the strain of interest by using primers 34 and 45.

Chromosomal DNA from potential cypX deletants was isolated using the REDextract-N-Amp™ Plant PCR kits as follows: Single *Bacillus* colonies were inoculated into 100 µl of Extraction Solution, incubated at 95° C. for 10 minutes, and then diluted with an equal volume of Dilution Solution. PCR was performed using 4 µl of extracted DNA in conjunction with the REDextract-N-Amp™ PCR Reaction Mix and the desired primers according to the manufacturer’s instructions, using PCR cycling conditions as described in Example 5. PCR reaction products were visualized using a 0.8% agarose-0.5×TBE gel. The verified strain was designated *Bacillus subtilis* RB197.

Example 13

Construction of *Bacillus subtilis* RB200

The cypX gene of *Bacillus subtilis* RB192 was deleted using the same methods described in Example 9 for *Bacillus subtilis* RB187. The resultant strain was designated *Bacillus subtilis* RB200.

Example 14

Construction of *Bacillus subtilis* RB202

Bacillus subtilis A164Δ5ΔcypX was constructed as follows: Plasmid pMRT122 (Example 12) was transformed into *Bacillus subtilis* A164Δ5 competent cells. Transformants were selected on TBAB-agar plates supplemented with 1 µg of erythromycin and 25 µg of lincomycin per ml after incubation at 30° C. for 24-48 hours. The plasmid was introduced into the chromosome of *Bacillus subtilis* A164Δ5 via homologous recombination into the cypX locus by incubating a freshly streaked plate of *Bacillus subtilis* A164Δ5 (pMRT086) cells at 450 for 16 hours and selecting for healthy growing colonies. The plasmid was removed from the chromosome via homologous recombination resulting in the deletion of a portion of the cypX gene on the chromosome by growing the transformants in Luria-Bertani (LB) medium without selection at the permissive temperature of 34° C. for many generations. At this temperature the pE194 origin of replication is active and actually promotes the excision of the plasmid from the chromosome (*Molecular Biological Methods for Bacillus*, edited by C. R. Harwood and S. M. Cutting, 1990, John Wiley and Sons Ltd.). After several generations of outgrowth the cells were plated on non-selective LB agar plates and colonies which had lost the plasmid and were now cypX-deleted were identified as follows: (1) erythromycin sensitivity indicated loss of the pE194-based plasmid, and (2) PCR confirmed the presence of the 800 bp cypX deletion in

the strain of interest by using primers 34 and 45 as described above. The verified strain was designated *Bacillus subtilis* A164Δ5ΔcypX.

Bacillus subtilis A164Δ5ΔcypX was made competent and transformed with *Bacillus subtilis* TH1 genomic DNA (Example 7) isolated using a QIAGEN tip-20 column according to the manufacturer’s instructions. Transformants were selected on TBAB plates containing 5 µg of chloramphenicol per ml at 37° C. The *Bacillus subtilis* A164Δ5ΔcypX hasA/hasB/hasC/hasD integrant was identified by its “wet” phenotype and designated *Bacillus subtilis* RB201. The cat gene was deleted from *Bacillus subtilis* RB201 using the same method described in Example 9. The resultant strain was designated *Bacillus subtilis* RB202.

Example 15

Construction of *Bacillus subtilis* MF002 (tuaD/gtaB)

Plasmid pHA3 (Example 2, FIG. 9) was digested with Asp718. The digested plasmid was then blunted by first inactivating the restriction enzyme at 85° C. for 30 minutes. Blunting was performed by adding 0.5 µl of 10 mM each dNTPs, 1 µl of 1 U/µl T4 polymerase and incubating at 11° C. for 10 minutes. Finally the polymerase was inactivated by incubating the reaction at 75° C. for 10 minutes. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer’s instructions and finally digested with NotI. The smallest plasmid fragment of approximately 2522 bp was then gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer’s instructions. The recovered DNA insert (tuaD/gtaB) was then ligated with the vector DNA described below.

Plasmid pDG268MCSΔneo/scBAN/Sav (U.S. Pat. No. 5,955,310) was digested with Ecl136II. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer’s instructions, and finally digested with NotI. The largest plasmid fragment of approximately 6800 bp was gel-purified from a 0.8% agarose-0.5×TBE gel using a QIAquick DNA Gel Extraction Kit according to the manufacturer’s instructions.

The recovered vector and DNA insert were ligated using the Rapid DNA Cloning Kit according to the manufacturer’s instructions. Prior to transformation in *Bacillus subtilis*, the ligation described above was linearized using Scat to ensure double cross-over integration in the chromosome rather than single cross-over integration in the chromosome. *Bacillus subtilis* 168Δ4 competent cells were transformed with the ligation digested with the restriction enzyme ScaI.

Bacillus subtilis chloramphenicol-resistant transformants were selected on TBAB plates supplemented with 5 µg of chloramphenicol per ml. To screen for integration of the plasmid by double cross-over at the amyE locus, *Bacillus subtilis* primary transformants were patched on TBAB plates supplemented with 6 µg of neomycin per ml and on TBAB plates supplemented with 5 µg of chloramphenicol per ml to isolate chloramphenicol resistant and neomycin sensitive transformants were isolated.

Chromosomal DNA from chloramphenicol resistant and neomycin sensitive *Bacillus subtilis* 168Δ4 transformants was isolated using the REDextract-N-Amp™ Plant PCR kits (Sigma Chemical Company, St. Louis, Mo.) as follows: Single *Bacillus* colonies were inoculated into 100 µl of Extraction Solution, incubated at 95° C. for 10 minutes, and then diluted with an equal volume of Dilution Solution. PCR was performed using 4 µl of extracted DNA in conjunction

with the REDextract-N-Amp PCR Reaction Mix and the desired primers according to the manufacturer's instructions, with PCR cycling conditions described in Example 5.

PCR amplifications were performed on these transformants using the synthetic oligonucleotides described below to confirm the absence/presence and integrity of the genes *hasA*, *gtaB*, and *tuaD* of the operon of the *Bacillus subtilis* transformants. Primers 3 and 8 were used to confirm the absence of the *hasA* gene, primer 71 and primer 15 to confirm the presence of the *tuaD* gene, and primers 20 and 71 to confirm the presence of the *gtaB* gene. PCR reaction products were visualized in a 0.8% agarose-0.5×TBE gel. The verified strain, a *Bacillus subtilis* 168Δ4 *hasA/tuaD/gtaB* integrant, was designated *Bacillus subtilis* RB176.

Primer 71: 5'-AACTATTGCCGATGATAAGC-3' (binds upstream of *tuaD*) (SEQ ID NO: 85)

Genomic DNA was isolated from the chloramphenicol resistant, and neomycin sensitive *Bacillus subtilis* RB176 transformants using a QIAGEN tip-20 column according to the manufacturer's instructions. The *Bacillus subtilis* RB176 genomic DNA was used to transform competent *Bacillus subtilis* A164Δ5. Transformants were selected on TBAB plates containing 5 μg of chloramphenicol per ml, and grown at 37° C. A *Bacillus subtilis* A164Δ5 *tuaD/gtaB* integrant was designated *Bacillus subtilis* RB177.

The *cat* gene was deleted in strain *Bacillus subtilis* RB177 using the method described in Example 9. The resultant strain was designated *Bacillus subtilis* MF002.

Example 16

Construction of the *pel* Integration Plasmid pRB162

Plasmid pDG268MCSΔneo/scBAN/Sav (U.S. Pat. No. 5,955,310) was double-digested with *SacI* and *AatII*. The largest plasmid fragment of approximately 6193 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered vector DNA was then ligated with the DNA insert described below.

The 5' and 3' fragments of a *Bacillus subtilis* pectate lyase gene (*pel*, accession number BG10840, SEQ ID NOS. 86 [DNA sequence] and 87 [deduced amino acid sequence]) was PCR amplified from *Bacillus subtilis* 168 (BGSC 1A1, *Bacillus* Genetic Stock Center, Columbus, Ohio) using primers 72 (introduces 5' *SpeI* restriction site) and 73 (introduces 3' *Sall* restriction site) for the 5' *pel* fragment and primers 74 (introduces 5' *SacI/BamHI* restriction sites) and 75 (introduces 3' *NotI/AatII* restriction sites) for the 3' *pel* fragment:

Primer 72:

5'-ACTAGTAATGATGGCTGGGGCGCGTA-3' (SEQ ID NO: 88)

Primer 73:

5'-GTCGACATGTTGTCGTATTGTGAGTT-3' (SEQ ID NO: 89)

Primer 74:

5'-GAGCTCTACAACGCTTATGGATCCGCG-GCCGCGGCGGCACACACATCTGGAT-3' (SEQ ID NO: 90)

Primer 75:

5'-GACGTCAGCCCGTTTGCAGCCGATGC-3' (SEQ ID NO: 91)

PCR amplifications were carried out in triplicate in 30 μl reactions composed of 50 ng of *Bacillus subtilis* 168 chromosomal DNA, 0.4 μM each of primer pair 72/73 for the 5' *pel* fragment or primer pair 74/75 for the 3' *pel* fragment, 200 μM each of dATP, dCTP, dGTP, and dTTP, 1×PCR Buffer II with

2.5 mM MgCl₂, and 2.5 units of AmpliTaq Gold™ DNA polymerase. The reactions were performed in a RoboCycler 40 thermacycler programmed for 1 cycle at 95° C. for 9 minutes; 3 cycles each at 95° C. for 1 minute, 52° C. for 1 minute, and 72° C. for 1 minute; 27 cycles each at 95° C. for 1 minute, 55° C. for 1 minute, and 72° C. for 1 minute; and 1 cycle at 72° C. for 5 minutes. The PCR products were visualized using a 0.8% agarose-0.5×TBE gel. The expected fragments were approximately 530 bp for the 5' *pel* fragment and 530 bp for the 3' *pel* fragment.

The 530 bp 5' *pel* and 530 bp 3' *pel* PCR fragments were cloned into pCR2.1 using the TA-TOPO Cloning Kit and transformed into *E. coli* OneShot™ competent cells according to the manufacturer's instructions. Transformants were selected on 2×YT agar plates supplemented with 100 μg of ampicillin per ml incubated at 37° C. Plasmid DNA from these transformants was purified using a QIAGEN robot according to the manufacturer's instructions and the DNA sequence of the inserts confirmed by DNA sequencing using the primers described above (primers 72 and 73 for 5' *pel* and primers 74 and 75 for 3' *pel*). The plasmids harboring the 530 bp and the 530 bp PCR fragments were designated pCR2.1-*pel* 5' and pCR2.1-*pel*3', respectively (FIGS. 38 and 39, respectively).

Plasmid pCR2.1-*pel*3' was double-digested with *SacI* and *AatII*. The smallest plasmid fragment of approximately 530 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions.

The recovered vector (pDG268MCSΔneo/scBAN) and DNA insert (3' *pel*) were ligated using the Rapid DNA Cloning Kit according to the manufacturer's instructions. The ligation mix was transformed into *E. coli* SURE competent cells (Stratagene, Inc., La Jolla, Calif.). Transformants were selected on 2×YT agar plates supplemented with 100 μg of ampicillin per ml at 37° C.

Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by *SacI* and *AatII* digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the presence of an approximately 530 bp *SacI/AatII* 3' *pel* fragment and was designated pRB161 (FIG. 40).

Plasmid pRB161 was double-digested with *SpeI* and *Sall*. The largest plasmid fragment of approximately 5346 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered vector DNA was then ligated with the DNA insert described below.

Plasmid pCR2.1-*pel*5' was double-digested with *SpeI* and *Sall*. The smallest plasmid fragment of approximately 530 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions.

The recovered vector (pDG268MCSΔneo/scBAN/*pel* 3') and insert (*pel* 5') DNA were ligated using the Rapid DNA Cloning Kit according to the manufacturer's instructions. The ligation mix was transformed into *E. coli* SURE competent cells (Stratagene, Inc., La Jolla, Calif.). Transformants were selected on 2×YT agar plates supplemented with 100 g of ampicillin per ml.

Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by *SpeI* and *Sall* digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid

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was identified by the presence of an approximately 530 bp SpeI/SalI pel 5' fragment and was designated pRB162 (FIG. 41).

Example 17

Construction of pRB156

Plasmid pHA7 (Example 4, FIG. 13) was digested with HpaI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions and finally digested with Asp718. The double-digested plasmid was then blunted by first inactivating the restriction enzyme at 85° C. for 30 minutes. Blunting was performed by adding 0.5 µl of 10 mM each dNTPs and 1 µl of 1 U/µl of T4 polymerase and incubating at 11° C. for 10 minutes. The polymerase was then inactivated by incubating the reaction at 75° C. for 10 minutes. The largest plasmid fragment of approximately 8600 bp was then gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered DNA insert (pDG268Δneo-cryII-Iastab/sehasA) was then re-ligated using the Rapid DNA Cloning Kit according to the manufacturer's instructions.

The ligation mix was transformed into *E. coli* SURE competent cells (Stratagene, Inc., La Jolla, Calif.). Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml at 37° C. Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by ScaI digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the presence of an approximately 8,755 bp fragment and was designated pRB156 (FIG. 42).

Example 18

Construction of *Bacillus subtilis* MF009

The hasA gene under control of the scBAN promoter was introduced into the pectate lyase gene (pel) locus of *Bacillus subtilis* MF002 to generate *Bacillus subtilis* MF009.

Plasmid pRB156 was digested with SacI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions, and finally digested with NotI. The smallest plasmid fragment of approximately 1,377 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered DNA insert was then ligated with the vector DNA described below.

Plasmid pRB162 (Example 16, FIG. 41) was digested with NotI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions, and finally digested with SacI. The largest plasmid fragment of approximately 5850 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered vector DNA was then ligated with the DNA insert described above.

The ligation mixture was transformed directly in *Bacillus subtilis* 168Δ4 competent cells. *Bacillus subtilis* chloramphenicol-resistant transformants were selected on TBAB plates supplemented with 5 µg of chloramphenicol per ml at 37° C. To screen for integration of the plasmid by double cross-over at the pel locus, *Bacillus subtilis* primary transformants were patched on TBAB plates supplemented with 6 µg of neomycin per ml and on TBAB plates supplemented with

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5 µg of chloramphenicol per ml. Integration of the plasmid by double cross-over at the pel locus does not incorporate the neomycin resistance gene and therefore renders the strain neomycin sensitive. Using this plate screen, chloramphenicol resistant and neomycin sensitive transformants were isolated.

Genomic DNA was isolated from the chloramphenicol resistant and neomycin sensitive *Bacillus subtilis* 168Δ4 transformants using a QIAGEN tip-20 column according to the manufacturer's instructions. This genomic DNA was used to transform competent *Bacillus subtilis* MF002 (Example 15). Transformants were selected on TBAB plates containing 5 µg of chloramphenicol per ml and grown at 37° C. The *Bacillus subtilis* A164Δ5 hasA and tuaD/gtaB integrant was identified by its "wet" phenotype and designated *Bacillus subtilis* MF009.

Example 19

Construction of *Bacillus subtilis* MF010

Plasmid pDG268MCSΔneo/BAN/Sav (U.S. Pat. No. 5,955,310) was digested with NotI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions, and finally digested with SfiI. The smallest plasmid fragment of approximately 185 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered DNA insert was then ligated with the vector DNA described below.

Plasmid pRB162 (Example 16, FIG. 41) was digested with NotI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions, and finally digested with SfiI. The largest plasmid fragment of approximately 5747 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered vector DNA was then ligated with the DNA insert described above.

The recovered vector and DNA insert were ligated using the Rapid DNA Cloning Kit according to the manufacturer's instructions. The ligation mix was transformed into *E. coli* XLI Blue competent cells. Transformants were selected on 2×YT agar plates supplemented with 100 µg of ampicillin per ml.

Plasmid DNA was purified from several transformants using a QIAGEN robot according to the manufacturer's instructions and analyzed by BamHI digestion on a 0.8% agarose gel using 0.5×TBE buffer. The correct plasmid was identified by the linearization of the plasmid which provides an approximately 7,156 bp fragment and was designated pRB164 (FIG. 43).

Plasmid pRB156 (Example 17, FIG. 42) was digested with SacI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions, and finally digested with NotI. The smallest plasmid fragment of approximately 1377 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel according to the manufacturer's instructions. The recovered DNA insert was then ligated with the vector DNA described below.

Plasmid pRB164 was digested with NotI. The digested plasmid was then purified using a QIAquick DNA Purification Kit according to the manufacturer's instructions, and finally digested with SacI. The largest plasmid fragment of approximately 5922 bp was gel-purified using a QIAquick DNA Gel Extraction Kit from a 0.8% agarose-0.5×TBE gel

according to the manufacturer's instructions. The recovered vector DNA was then ligated with the DNA insert described above.

This ligation mix was transformed directly in *Bacillus subtilis* 168Δ4 competent cells. *Bacillus subtilis* chloramphenicol-resistant transformants were selected on TBAB plates supplemented with 5 μg of chloramphenicol per ml at 37° C. To screen for integration of the plasmid by double cross-over at the amyE locus, *Bacillus subtilis* primary transformants were patched on TBAB plates supplemented with 6 μg of neomycin per ml and on TBAB plates supplemented with 5 μg of chloramphenicol per ml. Integration of the plasmid by double cross-over at the amyE locus does not incorporate the neomycin resistance gene and therefore renders the strain neomycin sensitive. Using this plate screen, chloramphenicol resistant and neomycin sensitive transformants were isolated.

Genomic DNA was isolated from the chloramphenicol resistant and neomycin sensitive *Bacillus subtilis* 168Δ4 transformants using a QIAGEN tip-20 column according to the manufacturer's instructions. This genomic DNA was used to transform competent *Bacillus subtilis* MF002 (Example 15). Transformants were selected on minimal plates containing 5 μg of chloramphenicol per ml and grown at 37° C. for 16 hours. A *Bacillus subtilis* A164Δ5 BAN/hasA and scBAN/tuaD/gtaB integrant was identified by its "wet" phenotype and designated *Bacillus subtilis* MF010.

Example 20

Fermentations

The ability of the *Bacillus subtilis* strains listed in Table 1 to produce hyaluronic acid was evaluated under various growth conditions.

TABLE 1

| <i>B. subtilis</i> Strain | promoter/gene complement | catΔ | cypXA |
|---------------------------|---------------------------|------|-------|
| RB161 | scBAN/hasA/tuaD/gtaB | no | no |
| RB163 | scBAN/hasA/tuaD/gcaD | no | no |
| TH-1 | scBAN/hasA/hasB/hasC/hasD | no | no |
| RB184 | scBAN/hasA/tuaD | no | no |
| RB187 | scBAN/hasA/tuaD/gtaB | yes | no |
| RB192 | scBAN/hasA/tuaD | yes | no |
| RB194 | scBAN/hasA/tuaD/gtaB | yes | yes |
| RB197 | scBAN/hasA/tuaD/gtaB | yes | yes |
| RB200 | scBAN/hasA/tuaD | yes | yes |
| RB202 | scBAN/hasA/hasB/hasC/hasD | yes | yes |
| MF009 | scBAN/tuaD/gtaB | no | no |
| | scBAN/hasA | | |
| MF010 | scBAN/tuaD/gtaB | no | no |
| | BAN/hasA | | |

The *Bacillus subtilis* strains were fermented in standard small fermenters in a medium composed per liter of 6.5 g of KH₂PO₄, 4.5 g of Na₂HPO₄, 3.0 g of (NH₄)₂SO₄, 2.0 g of Na₃-citrate-2H₂O, 3.0 g of MgSO₄·7H₂O, 6.0 ml of Mikrosoy-2, 0.15 mg of biotin (1 ml of 0.15 mg/ml ethanol), 15.0 g of sucrose, 1.0 ml of SB 2066, 2.0 ml of P2000, 0.5 g of CaCl₂·2H₂O. The medium was pH 6.3 to 6.4 (unadjusted) prior to autoclaving. The CaCl₂·2H₂O was added after autoclaving.

The seed medium used was B-3, i.e., Agar-3 without agar, or "S/S-1" medium. The Agar-3 medium was composed per liter of 4.0 g of nutrient broth, 7.5 g of hydrolyzed protein, 3.0 g of yeast extract, 1.0 g of glucose, and 2% agar. The pH was not adjusted; pH before autoclaving was approximately 6.8; after autoclaving approximately pH 7.7.

The sucrose/soy seed flask medium (S/S-1) was composed per liter of 65 g of sucrose, 35 g of soy flour, 2 g of Na₃-citrate·2H₂O, 4 g of KH₂PO₄, 5 g of Na₂HPO₄, and 6 ml of trace elements. The medium was adjusted pH to about 7 with NaOH; after dispensing the medium to flasks, 0.2% vegetable oil was added to suppress foaming. Trace elements was composed per liter of 100 g of citric acid-H₂O, 20 g of FeSO₄·7H₂O, 5 g of MnSO₄·H₂O, 2 g of CuSO₄·5H₂O, and 2 g of ZnCl₂.

The pH was adjusted to 6.8-7.0 with ammonia before inoculation, and controlled thereafter at pH 7.0±0.2 with ammonia and H₃PO₄. The temperature was maintained at 37° C. Agitation was at a maximum of 1300 RPM using two 6-bladed rushton impellers of 6 cm diameter in 3 liter tank with initial volume of 1.5 liters. The aeration had a maximum of 1.5 VVM.

For feed, a simple sucrose solution was used. Feed started at about 4 hours after inoculation, when dissolved oxygen (D.O.) was still being driven down (i.e., before sucrose depletion). The feed rate was ramped linearly from 0 to approximately 6 g sucrose/L₀-hr over a 7 hour time span. A lower feed rate, ramped linearly from 0 to approximately 2 g sucrose/L₀-hr, was also used in some fermentations.

Viscosity was noticeable by about 10 hours and by 24 hours viscosity was very high, causing the D.O. to bottom-out. End-point viscosity reached 3,220 cP. Cell mass development reached a near maximum (12 to 15 g/liter) by 20 hours. Cells were removed by diluting 1 part culture with 3 parts water, mixing well and centrifuging at about 30,000×g to produce a clear supernatant and cell pellet, which can be washed and dried.

Assays of hyaluronic acid concentration were performed using the ELISA method, based on a hyaluronan binding protein (protein and kits commercially available from Seikagaku America, Falmouth, Mass.).

Bacillus subtilis RB 161 and RB163 were cultured in batch and fed-batch fermentations. In the fed-batch processes, the feed rate was varied between cultures of *Bacillus subtilis* strains RB163 and RB161. Assays of hyaluronic acid concentrations were again performed using the ELISA method. The results are provided in Table 2.

TABLE 2

| Strain and Growth Conditions | HA (relative yield) ELISA method |
|---|----------------------------------|
| RB-161 (hasA/tuaD/gtaB) simple batch | 0.7 ± 0.1 |
| RB-163 (hasA/tuaD/gcaD) fed batch ~6 g sucrose/L ₀ -hr | 0.9 ± 0.1 |
| RB161 (hasA/tuaD/gtaB) fed batch ~6 g sucrose/L ₀ -hr | 0.9 ± 0.1 |
| RB-163 (hasA/tuaD/gcaD) fed batch ~2 g sucrose/L ₀ -hr | 1.0 ± 0.2 |
| RB161 (hasA/tuaD/gtaB) fed batch ~2 g sucrose/L ₀ -hr | 1.0 ± 0.1 |

The results of the culture assays for the same strain at a fed batch rate of 2 g/L sucrose/L₀-hr compared to 6 g/L sucrose/L₀-hr demonstrated that a faster sucrose feed rate did not significantly improve titers.

A summary of the *Bacillus* strains run under same conditions (fed batch at approximately 2 g sucrose/L₀-hr, 37° C.) is shown in FIG. 44. In FIG. 44, ± values indicate standard deviation of data from multiple runs under the same conditions. Data without ± values are from single runs. Hyaluronic acid concentrations were determined using the modified carbazole method (Bitter and Muir, 1962, *Anal Biochem.* 4: 330-334).

A summary of peak hyaluronic acid weight average molecular weights (MDa) obtained from fermentation of the recombinant *Bacillus subtilis* strains under the same conditions (fed batch at approximately 2 g sucrose/L₀-hr, 37° C.) is shown in FIG. 45. Molecular weights were determined using a GPC MALLS assay. Data was gathered from GPC MALLS assays using the following procedure. GPC-MALLS (gel permeation or size-exclusion) chromatography coupled with multi-angle laser light scattering) is widely used to characterize high molecular weight (MW) polymers. Separation of polymers is achieved by GPC, based on the differential partitioning of molecules of different MW between eluent and resin. The average molecular weight of an individual polymer is determined by MALLS based the differential scattering extent/angle of molecules of different MW. Principles of GPC-MALLS and protocols suited for hyaluronic acid are described by Ueno et al., 1988, *Chem. Pharm. Bull.* 36, 4971-4975; Wyatt, 1993, *Anal. Chim. Acta* 272: 1-40; and Wyatt Technologies, 1999, "Light Scattering University DAWN Course Manual" and "DAWN EOS Manual" Wyatt Technology Corporation, Santa Barbara, Calif.). An Agilent 1100 isocratic HPLC, a Tosoh Biosep G6000 PWxI column for the GPC, and a Wyatt Down EOS for the MALLS were used. An Agilent G1362A refractive index detector was linked downstream from the MALLS for eluate concentration determination. Various commercial hyaluronic acid products with known molecular weights served as standards.

Deposit of Biological Material

The following biological material has been deposited under the terms of the Budapest Treaty with the Agricultural

Research Service Patent Culture Collection, Northern Regional Research Center, 1815 University Street, Peoria, Ill., 61604, and given the following accession number:

| Deposit | Accession Number | Date of Deposit |
|--|------------------|-----------------|
| <i>E. coli</i> XL10 Gold kan (pMRT106) | NRRL B-30536 | Dec. 12, 2001 |

The strain has been deposited under conditions that assure that access to the culture will be available during the pendency of this patent application to one determined by the Commissioner of Patents and Trademarks to be entitled thereto under 37 C.F.R. §1.14 and 35 U.S.C. §122. The deposit represents a substantially pure culture of the deposited strain. The deposit is available as required by foreign patent laws in countries wherein counterparts of the subject application, or its progeny are filed. However, it should be understood that the availability of a deposit does not constitute a license to practice the subject invention in derogation of patent rights granted by governmental action.

The invention described and claimed herein is not to be limited in scope by the specific embodiments herein disclosed, since these embodiments are intended as illustrations of several aspects of the invention. Any equivalent embodiments are intended to be within the scope of this invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims. In the case of conflict, the present disclosure including definitions will control.

Various references are cited herein, the disclosures of which are incorporated by reference in their entireties.

SEQUENCE LISTING

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<210> SEQ ID NO 1

<211> LENGTH: 1251

<212> TYPE: DNA

<213> ORGANISM: *Streptococcus equisimilis*

<220> FEATURE:

<221> NAME/KEY: CDS

<222> LOCATION: (1)..(1251)

<400> SEQUENCE: 1

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1           5           10           15

tgg gta ctg ttg att tac gtc aat gtt tat ctc ttt ggt gct aaa gga      96
Trp Val Leu Leu Ile Tyr Val Asn Val Tyr Leu Phe Gly Ala Lys Gly
20           25           30

agc ttg tca att tat ggc ttt ttg ctg ata gct tac cta tta gtc aaa      144
Ser Leu Ser Ile Tyr Gly Phe Leu Leu Ile Ala Tyr Leu Leu Val Lys
35           40           45

atg tcc tta tcc ttt ttt tac aag cca ttt aag gga agg gct ggg caa      192
Met Ser Leu Ser Phe Phe Tyr Lys Pro Phe Lys Gly Arg Ala Gly Gln
50           55           60

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-continued

| | |
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| 65 70 75 80 | |
| ttg cta gag acc tta aaa agt gtt cag cag caa acc tat ccc cta gca | 288 |
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| 85 90 95 | |
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| 100 105 110 | |
| cgc att gaa gac tat gtg cgt gac act ggt gac cta tca agc aat gtc | 384 |
| Arg Ile Glu Asp Tyr Val Arg Asp Thr Gly Asp Leu Ser Ser Asn Val | |
| 115 120 125 | |
| att gtt cac cgg tca gaa aaa aat caa gga aag cgt cat gca cag gcc | 432 |
| Ile Val His Arg Ser Glu Lys Asn Gln Gly Lys Arg His Ala Gln Ala | |
| 130 135 140 | |
| tgg gcc ttt gaa aga tca gac gct gat gtc ttt ttg acc gtt gac tca | 480 |
| Trp Ala Phe Glu Arg Ser Asp Ala Asp Val Phe Leu Thr Val Asp Ser | |
| 145 150 155 160 | |
| gat act tat atc tac cct gat gct tta gag gag ttg tta aaa acc ttt | 528 |
| Asp Thr Tyr Ile Tyr Pro Asp Ala Leu Glu Glu Leu Leu Lys Thr Phe | |
| 165 170 175 | |
| aat gac cca act gtt ttt gct gcg acg ggt cac ctt aat gtc aga aat | 576 |
| Asn Asp Pro Thr Val Phe Ala Ala Thr Gly His Leu Asn Val Arg Asn | |
| 180 185 190 | |
| aga caa acc aat ctc tta aca cgc ttg aca gat att cgc tat gat aat | 624 |
| Arg Gln Thr Asn Leu Leu Thr Arg Leu Thr Asp Ile Arg Tyr Asp Asn | |
| 195 200 205 | |
| gct ttt ggc gtt gaa cga gct gcc caa tcc gtt aca ggt aat att ctc | 672 |
| Ala Phe Gly Val Glu Arg Ala Ala Gln Ser Val Thr Gly Asn Ile Leu | |
| 210 215 220 | |
| gtt tgc tca ggc ccg ctt agc gtt tac aga cgc gag gtg gtt gtt cct | 720 |
| Val Cys Ser Gly Pro Leu Ser Val Tyr Arg Arg Glu Val Val Val Pro | |
| 225 230 235 240 | |
| aac ata gat aga tac atc aac cag acc ttc ctg ggt att cct gta agt | 768 |
| Asn Ile Asp Arg Tyr Ile Asn Gln Thr Phe Leu Gly Ile Pro Val Ser | |
| 245 250 255 | |
| atc ggt gat gac agg tgc ttg acc aac tat gca act gat tta gga aag | 816 |
| Ile Gly Asp Asp Arg Cys Leu Thr Asn Tyr Ala Thr Asp Leu Gly Lys | |
| 260 265 270 | |
| act gtt tat caa tcc act gct aaa tgt att aca gat gtt cct gac aag | 864 |
| Thr Val Tyr Gln Ser Thr Ala Lys Cys Ile Thr Asp Val Pro Asp Lys | |
| 275 280 285 | |
| atg tct act tac ttg aag cag caa aac cgc tgg aac aag tcc ttc ttt | 912 |
| Met Ser Thr Tyr Leu Lys Gln Gln Asn Arg Trp Asn Lys Ser Phe Phe | |
| 290 295 300 | |
| aga gag tcc att att tct gtt aag aaa atc atg aac aat cct ttt gta | 960 |
| Arg Glu Ser Ile Ile Ser Val Lys Lys Ile Met Asn Asn Pro Phe Val | |
| 305 310 315 320 | |
| gcc cta tgg acc ata ctt gag gtg tct atg ttt atg atg ctt gtt tat | 1008 |
| Ala Leu Trp Thr Ile Leu Glu Val Ser Met Phe Met Met Leu Val Tyr | |
| 325 330 335 | |
| tct gtg gtg gat ttc ttt gta gac aat gtc aga gaa ttt gat tgg ctc | 1056 |
| Ser Val Val Asp Phe Phe Val Asp Asn Val Arg Glu Phe Asp Trp Leu | |
| 340 345 350 | |
| agg gtt ttg gcc ttt ctg gtg att atc ttc att gtt gct ctt tgt cgt | 1104 |
| Arg Val Leu Ala Phe Leu Val Ile Ile Phe Ile Val Ala Leu Cys Arg | |
| 355 360 365 | |
| aat att cac tat atg ctt aag cac ccg ctg tcc ttc ttg tta tct ccg | 1152 |
| Asn Ile His Tyr Met Leu Lys His Pro Leu Ser Phe Leu Leu Ser Pro | |
| 370 375 380 | |

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| | |
|---|------|
| ttt tat ggg gta ctg cat ttg ttt gtc cta cag ccc ttg aaa ttg tat | 1200 |
| Phe Tyr Gly Val Leu His Leu Phe Val Leu Gln Pro Leu Lys Leu Tyr | |
| 385 390 395 400 | |
| tct ctt ttt act att aga aat gct gac tgg gga aca cgt aaa aaa tta | 1248 |
| Ser Leu Phe Thr Ile Arg Asn Ala Asp Trp Gly Thr Arg Lys Lys Leu | |
| 405 410 415 | |
| tta | 1251 |
| Leu | |
| | |
| <210> SEQ ID NO 2 | |
| <211> LENGTH: 417 | |
| <212> TYPE: PRT | |
| <213> ORGANISM: Streptococcus equisimilis | |
| | |
| <400> SEQUENCE: 2 | |
| Met Arg Thr Leu Lys Asn Leu Ile Thr Val Val Ala Phe Ser Ile Phe | |
| 1 5 10 15 | |
| Trp Val Leu Leu Ile Tyr Val Asn Val Tyr Leu Phe Gly Ala Lys Gly | |
| 20 25 30 | |
| Ser Leu Ser Ile Tyr Gly Phe Leu Leu Ile Ala Tyr Leu Leu Val Lys | |
| 35 40 45 | |
| Met Ser Leu Ser Phe Phe Tyr Lys Pro Phe Lys Gly Arg Ala Gly Gln | |
| 50 55 60 | |
| Tyr Lys Val Ala Ala Ile Ile Pro Ser Tyr Asn Glu Asp Ala Glu Ser | |
| 65 70 75 80 | |
| Leu Leu Glu Thr Leu Lys Ser Val Gln Gln Gln Thr Tyr Pro Leu Ala | |
| 85 90 95 | |
| Glu Ile Tyr Val Val Asp Asp Gly Ser Ala Asp Glu Thr Gly Ile Lys | |
| 100 105 110 | |
| Arg Ile Glu Asp Tyr Val Arg Asp Thr Gly Asp Leu Ser Ser Asn Val | |
| 115 120 125 | |
| Ile Val His Arg Ser Glu Lys Asn Gln Gly Lys Arg His Ala Gln Ala | |
| 130 135 140 | |
| Trp Ala Phe Glu Arg Ser Asp Ala Asp Val Phe Leu Thr Val Asp Ser | |
| 145 150 155 160 | |
| Asp Thr Tyr Ile Tyr Pro Asp Ala Leu Glu Glu Leu Leu Lys Thr Phe | |
| 165 170 175 | |
| Asn Asp Pro Thr Val Phe Ala Ala Thr Gly His Leu Asn Val Arg Asn | |
| 180 185 190 | |
| Arg Gln Thr Asn Leu Leu Thr Arg Leu Thr Asp Ile Arg Tyr Asp Asn | |
| 195 200 205 | |
| Ala Phe Gly Val Glu Arg Ala Ala Gln Ser Val Thr Gly Asn Ile Leu | |
| 210 215 220 | |
| Val Cys Ser Gly Pro Leu Ser Val Tyr Arg Arg Glu Val Val Val Pro | |
| 225 230 235 240 | |
| Asn Ile Asp Arg Tyr Ile Asn Gln Thr Phe Leu Gly Ile Pro Val Ser | |
| 245 250 255 | |
| Ile Gly Asp Asp Arg Cys Leu Thr Asn Tyr Ala Thr Asp Leu Gly Lys | |
| 260 265 270 | |
| Thr Val Tyr Gln Ser Thr Ala Lys Cys Ile Thr Asp Val Pro Asp Lys | |
| 275 280 285 | |
| Met Ser Thr Tyr Leu Lys Gln Gln Asn Arg Trp Asn Lys Ser Phe Phe | |
| 290 295 300 | |
| Arg Glu Ser Ile Ile Ser Val Lys Lys Ile Met Asn Asn Pro Phe Val | |
| 305 310 315 320 | |
| Ala Leu Trp Thr Ile Leu Glu Val Ser Met Phe Met Met Leu Val Tyr | |

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| | | |
|---|-----|-----|
| 325 | 330 | 335 |
| Ser Val Val Asp Phe Phe Val Asp Asn Val Arg Glu Phe Asp Trp Leu | | |
| 340 | 345 | 350 |
| Arg Val Leu Ala Phe Leu Val Ile Ile Phe Ile Val Ala Leu Cys Arg | | |
| 355 | 360 | 365 |
| Asn Ile His Tyr Met Leu Lys His Pro Leu Ser Phe Leu Leu Ser Pro | | |
| 370 | 375 | 380 |
| Phe Tyr Gly Val Leu His Leu Phe Val Leu Gln Pro Leu Lys Leu Tyr | | |
| 385 | 390 | 395 |
| Ser Leu Phe Thr Ile Arg Asn Ala Asp Trp Gly Thr Arg Lys Lys Leu | | |
| 405 | 410 | 415 |

Leu

<210> SEQ ID NO 3
 <211> LENGTH: 49
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 3

gagctctata aaaatgagga gggaaccgaa tgagaacatt aaaaaacct 49

<210> SEQ ID NO 4
 <211> LENGTH: 48
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 4

gttaacgaat tcagctatgt aggtacctta taataatttt ttacgtgt 48

<210> SEQ ID NO 5
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 5

gttgacgatg gaagtgctga 20

<210> SEQ ID NO 6
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 6

atccgttaca ggtaatatcc 20

<210> SEQ ID NO 7
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 7

tccttttgta gccctatgga 20

<210> SEQ ID NO 8
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 8

tcagcacttc catcgtcaac 20

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<210> SEQ ID NO 9
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 9

ggatattacc tgtaacggat                                     20

<210> SEQ ID NO 10
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 10

tccatagggc taaaaagga                                     20

<210> SEQ ID NO 11
<211> LENGTH: 1383
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(1383)

<400> SEQUENCE: 11

gtg aaa aaa ata gct gtc att gga aca ggt tat gta gga ctc gta tca      48
Val Lys Lys Ile Ala Val Ile Gly Thr Gly Tyr Val Gly Leu Val Ser
1                               5                               10                               15

ggc act tgc ttt gcg gag atc ggc aat aaa gtt gtt tgc tgt gat atc      96
Gly Thr Cys Phe Ala Glu Ile Gly Asn Lys Val Val Cys Cys Asp Ile
20                               25                               30

gat gaa tca aaa atc aga agc ctg aaa aat ggg gta atc cca atc tat      144
Asp Glu Ser Lys Ile Arg Ser Leu Lys Asn Gly Val Ile Pro Ile Tyr
35                               40                               45

gaa cca ggg ctt gca gac tta gtt gaa aaa aat gtg ctg gat cag cgc      192
Glu Pro Gly Leu Ala Asp Leu Val Glu Lys Asn Val Leu Asp Gln Arg
50                               55                               60

ctg acc ttt acg aac gat atc ccg tct gcc att cgg gcc tca gat att      240
Leu Thr Phe Thr Asn Asp Ile Pro Ser Ala Ile Arg Ala Ser Asp Ile
65                               70                               75                               80

att tat att gca gtc gga acg cct atg tcc aaa aca ggt gaa gct gat      288
Ile Tyr Ile Ala Val Gly Thr Pro Met Ser Lys Thr Gly Glu Ala Asp
85                               90                               95

tta acg tac gtc aaa gcg gcg gcg aaa aca atc ggt gag cat ctt aac      336
Leu Thr Tyr Val Lys Ala Ala Ala Lys Thr Ile Gly Glu His Leu Asn
100                              105                              110

ggc tac aaa gtg atc gta aat aaa agc aca gtc ccg gtt gga aca ggg      384
Gly Tyr Lys Val Ile Val Asn Lys Ser Thr Val Pro Val Gly Thr Gly
115                              120                              125

aaa ctg gtg caa tct atc gtt caa aaa gcc tca aag ggg aga tac tca      432
Lys Leu Val Gln Ser Ile Val Gln Lys Ala Ser Lys Gly Arg Tyr Ser
130                              135                              140

ttt gat gtt gta tct aac cct gaa ttc ctt cgg gaa ggg tca gcg att      480
Phe Asp Val Val Ser Asn Pro Glu Phe Leu Arg Glu Gly Ser Ala Ile
145                              150                              155                              160

cat gac acg atg aat atg gag cgt gcc gtg att ggt tca aca agt cat      528
His Asp Thr Met Asn Met Glu Arg Ala Val Ile Gly Ser Thr Ser His
165                              170                              175

aaa gcc gct gcc atc att gag gaa ctt cat cag cca ttc cat gct cct      576
Lys Ala Ala Ala Ile Ile Glu Glu Leu His Gln Pro Phe His Ala Pro
180                              185                              190

gtc att aaa aca aac cta gaa agt gca gaa atg att aaa tac gcc gcg      624
Val Ile Lys Thr Asn Leu Glu Ser Ala Glu Met Ile Lys Tyr Ala Ala

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| 195 | 200 | 205 | |
|---|-----|-----|------|
| aat gca ttt ctg gcg aca aag att tcc ttt atc aac gat atc gca aac | | | 672 |
| Asn Ala Phe Leu Ala Thr Lys Ile Ser Phe Ile Asn Asp Ile Ala Asn | | | |
| 210 | 215 | 220 | |
| att tgt gag cga gtc ggc gca gac gtt tca aaa gtt gct gat ggt gtt | | | 720 |
| Ile Cys Glu Arg Val Gly Ala Asp Val Ser Lys Val Ala Asp Gly Val | | | |
| 225 | 230 | 235 | 240 |
| ggt ctt gac agc cgt atc ggc aga aag ttc ctt aaa gct ggt att gga | | | 768 |
| Gly Leu Asp Ser Arg Ile Gly Arg Lys Phe Leu Lys Ala Gly Ile Gly | | | |
| | 245 | 250 | 255 |
| ttc ggc ggt tca tgt ttt cca aag gat aca acc gcg ctg ctt caa atc | | | 816 |
| Phe Gly Gly Ser Cys Phe Pro Lys Asp Thr Thr Ala Leu Leu Gln Ile | | | |
| | 260 | 265 | 270 |
| gca aaa tcg gca ggc tat cca ttc aag ctc atc gaa gct gtc att gaa | | | 864 |
| Ala Lys Ser Ala Gly Tyr Pro Phe Lys Leu Ile Glu Ala Val Ile Glu | | | |
| | 275 | 280 | 285 |
| acg aac gaa aag cag cgt gtt cat att gta gat aaa ctt ttg act gtt | | | 912 |
| Thr Asn Glu Lys Gln Arg Val His Ile Val Asp Lys Leu Leu Thr Val | | | |
| | 290 | 295 | 300 |
| atg gga agc gtc aaa ggg aga acc att tca gtc ctg gga tta gcc ttc | | | 960 |
| Met Gly Ser Val Lys Gly Arg Thr Ile Ser Val Leu Gly Leu Ala Phe | | | |
| 305 | 310 | 315 | 320 |
| aaa ccg aat acg aac gat gtg aga tcc gct cca gcg ctt gat att atc | | | 1008 |
| Lys Pro Asn Thr Asn Asp Val Arg Ser Ala Pro Ala Leu Asp Ile Ile | | | |
| | 325 | 330 | 335 |
| cca atg ctg cag cag ctg ggc gcc cat gta aaa gca tac gat ccg att | | | 1056 |
| Pro Met Leu Gln Gln Leu Gly Ala His Val Lys Ala Tyr Asp Pro Ile | | | |
| | 340 | 345 | 350 |
| gct att cct gaa gct tca gcg atc ctt ggc gaa cag gtc gag tat tac | | | 1104 |
| Ala Ile Pro Glu Ala Ser Ala Ile Leu Gly Glu Gln Val Glu Tyr Tyr | | | |
| | 355 | 360 | 365 |
| aca gat gtg tat gct gcg atg gaa gac act gat gca tgc ctg att tta | | | 1152 |
| Thr Asp Val Tyr Ala Ala Met Glu Asp Thr Asp Ala Cys Leu Ile Leu | | | |
| | 370 | 375 | 380 |
| acg gat tgg ccg gaa gtg aaa gaa atg gag ctt gta aaa gtg aaa acc | | | 1200 |
| Thr Asp Trp Pro Glu Val Lys Glu Met Glu Leu Val Lys Val Lys Thr | | | |
| 385 | 390 | 395 | 400 |
| ctc tta aaa cag cca gtc atc att gac ggc aga aat tta ttt tca ctt | | | 1248 |
| Leu Leu Lys Gln Pro Val Ile Ile Asp Gly Arg Asn Leu Phe Ser Leu | | | |
| | 405 | 410 | 415 |
| gaa gag atg cag gca gcc gga tac att tat cac tct atc ggc cgt ccc | | | 1296 |
| Glu Glu Met Gln Ala Ala Gly Tyr Ile Tyr His Ser Ile Gly Arg Pro | | | |
| | 420 | 425 | 430 |
| gct gtt cgg gga acg gaa ccc tct gac aag tat ttt ccg ggc ttg ccg | | | 1344 |
| Ala Val Arg Gly Thr Glu Pro Ser Asp Lys Tyr Phe Pro Gly Leu Pro | | | |
| | 435 | 440 | 445 |
| ctt gaa gaa ttg gct aaa gac ttg gga agc gtc aat tta | | | 1383 |
| Leu Glu Glu Leu Ala Lys Asp Leu Gly Ser Val Asn Leu | | | |
| | 450 | 455 | 460 |

<210> SEQ ID NO 12

<211> LENGTH: 461

<212> TYPE: PRT

<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 12

| | | | |
|---|----|----|----|
| Val Lys Lys Ile Ala Val Ile Gly Thr Gly Tyr Val Gly Leu Val Ser | | | |
| 1 | 5 | 10 | 15 |
| Gly Thr Cys Phe Ala Glu Ile Gly Asn Lys Val Val Cys Cys Asp Ile | | | |
| | 20 | 25 | 30 |

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| | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Asp | Glu | Ser | Lys | Ile | Arg | Ser | Leu | Lys | Asn | Gly | Val | Ile | Pro | Ile | Tyr |
| | | 35 | | | | | 40 | | | | | 45 | | | |
| Glu | Pro | Gly | Leu | Ala | Asp | Leu | Val | Glu | Lys | Asn | Val | Leu | Asp | Gln | Arg |
| | 50 | | | | | 55 | | | | | 60 | | | | |
| Leu | Thr | Phe | Thr | Asn | Asp | Ile | Pro | Ser | Ala | Ile | Arg | Ala | Ser | Asp | Ile |
| 65 | | | | | 70 | | | | | 75 | | | | | 80 |
| Ile | Tyr | Ile | Ala | Val | Gly | Thr | Pro | Met | Ser | Lys | Thr | Gly | Glu | Ala | Asp |
| | | | | 85 | | | | | 90 | | | | | 95 | |
| Leu | Thr | Tyr | Val | Lys | Ala | Ala | Ala | Lys | Thr | Ile | Gly | Glu | His | Leu | Asn |
| | | | 100 | | | | | 105 | | | | | 110 | | |
| Gly | Tyr | Lys | Val | Ile | Val | Asn | Lys | Ser | Thr | Val | Pro | Val | Gly | Thr | Gly |
| | | 115 | | | | | 120 | | | | | 125 | | | |
| Lys | Leu | Val | Gln | Ser | Ile | Val | Gln | Lys | Ala | Ser | Lys | Gly | Arg | Tyr | Ser |
| | 130 | | | | | 135 | | | | | 140 | | | | |
| Phe | Asp | Val | Val | Ser | Asn | Pro | Glu | Phe | Leu | Arg | Glu | Gly | Ser | Ala | Ile |
| 145 | | | | | 150 | | | | | 155 | | | | | 160 |
| His | Asp | Thr | Met | Asn | Met | Glu | Arg | Ala | Val | Ile | Gly | Ser | Thr | Ser | His |
| | | | | 165 | | | | | 170 | | | | | 175 | |
| Lys | Ala | Ala | Ala | Ile | Ile | Glu | Glu | Leu | His | Gln | Pro | Phe | His | Ala | Pro |
| | | | 180 | | | | | 185 | | | | | 190 | | |
| Val | Ile | Lys | Thr | Asn | Leu | Glu | Ser | Ala | Glu | Met | Ile | Lys | Tyr | Ala | Ala |
| | | 195 | | | | | 200 | | | | | 205 | | | |
| Asn | Ala | Phe | Leu | Ala | Thr | Lys | Ile | Ser | Phe | Ile | Asn | Asp | Ile | Ala | Asn |
| | 210 | | | | | 215 | | | | | 220 | | | | |
| Ile | Cys | Glu | Arg | Val | Gly | Ala | Asp | Val | Ser | Lys | Val | Ala | Asp | Gly | Val |
| 225 | | | | | 230 | | | | | 235 | | | | | 240 |
| Gly | Leu | Asp | Ser | Arg | Ile | Gly | Arg | Lys | Phe | Leu | Lys | Ala | Gly | Ile | Gly |
| | | | | 245 | | | | | 250 | | | | | 255 | |
| Phe | Gly | Gly | Ser | Cys | Phe | Pro | Lys | Asp | Thr | Thr | Ala | Leu | Leu | Gln | Ile |
| | | | 260 | | | | | 265 | | | | | 270 | | |
| Ala | Lys | Ser | Ala | Gly | Tyr | Pro | Phe | Lys | Leu | Ile | Glu | Ala | Val | Ile | Glu |
| | | 275 | | | | | 280 | | | | | 285 | | | |
| Thr | Asn | Glu | Lys | Gln | Arg | Val | His | Ile | Val | Asp | Lys | Leu | Leu | Thr | Val |
| | 290 | | | | | 295 | | | | | 300 | | | | |
| Met | Gly | Ser | Val | Lys | Gly | Arg | Thr | Ile | Ser | Val | Leu | Gly | Leu | Ala | Phe |
| 305 | | | | | 310 | | | | | 315 | | | | | 320 |
| Lys | Pro | Asn | Thr | Asn | Asp | Val | Arg | Ser | Ala | Pro | Ala | Leu | Asp | Ile | Ile |
| | | | | 325 | | | | | 330 | | | | | 335 | |
| Pro | Met | Leu | Gln | Gln | Leu | Gly | Ala | His | Val | Lys | Ala | Tyr | Asp | Pro | Ile |
| | | | 340 | | | | | 345 | | | | | 350 | | |
| Ala | Ile | Pro | Glu | Ala | Ser | Ala | Ile | Leu | Gly | Glu | Gln | Val | Glu | Tyr | Tyr |
| | | 355 | | | | | 360 | | | | | 365 | | | |
| Thr | Asp | Val | Tyr | Ala | Ala | Met | Glu | Asp | Thr | Asp | Ala | Cys | Leu | Ile | Leu |
| | 370 | | | | | 375 | | | | | 380 | | | | |
| Thr | Asp | Trp | Pro | Glu | Val | Lys | Glu | Met | Glu | Leu | Val | Lys | Val | Lys | Thr |
| 385 | | | | | 390 | | | | | 395 | | | | | 400 |
| Leu | Leu | Lys | Gln | Pro | Val | Ile | Ile | Asp | Gly | Arg | Asn | Leu | Phe | Ser | Leu |
| | | | | 405 | | | | | 410 | | | | | 415 | |
| Glu | Glu | Met | Gln | Ala | Ala | Gly | Tyr | Ile | Tyr | His | Ser | Ile | Gly | Arg | Pro |
| | | | 420 | | | | | 425 | | | | | 430 | | |
| Ala | Val | Arg | Gly | Thr | Glu | Pro | Ser | Asp | Lys | Tyr | Phe | Pro | Gly | Leu | Pro |
| | | 435 | | | | | 440 | | | | | 445 | | | |
| Leu | Glu | Glu | Leu | Ala | Lys | Asp | Leu | Gly | Ser | Val | Asn | Leu | | | |
| | 450 | | | | | 455 | | | | | 460 | | | | |

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<210> SEQ ID NO 13
<211> LENGTH: 26
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 13
ggtaccgaca ctgcgacat tataaa 26

<210> SEQ ID NO 14
<211> LENGTH: 49
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 14
gttaacgaat tccagctatg tatctagaca gttcaacca agtaacact 49

<210> SEQ ID NO 15
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 15
agcatcttaa cggctacaaa 20

<210> SEQ ID NO 16
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 16
tgtgagcgag tcggcgaga 20

<210> SEQ ID NO 17
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 17
gggcgccat gtaaaagcat 20

<210> SEQ ID NO 18
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 18
ttttagccg ttaagatgct 20

<210> SEQ ID NO 19
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 19
tctgcgccga ctcgctcaca 20

<210> SEQ ID NO 20
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 20
atgcttttac atggcgccc 20

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<210> SEQ ID NO 21
<211> LENGTH: 876
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(876)

<400> SEQUENCE: 21

atg aaa aaa gta cgt aaa gcc ata att cca gca gca ggc tta gga aca      48
Met Lys Lys Val Arg Lys Ala Ile Ile Pro Ala Ala Gly Leu Gly Thr
1          5          10          15

cgt ttt ctt ccg gct acg aaa gca atg ccg aaa gaa atg ctt cct atc      96
Arg Phe Leu Pro Ala Thr Lys Ala Met Pro Lys Glu Met Leu Pro Ile
          20          25          30

gtt gat aaa cct acc att caa tac ata att gaa gaa gct gtt gaa gcc     144
Val Asp Lys Pro Thr Ile Gln Tyr Ile Ile Glu Glu Ala Val Glu Ala
          35          40          45

ggt att gaa gat att att atc gta aca gga aaa agc aag cgt gcg att     192
Gly Ile Glu Asp Ile Ile Ile Val Thr Gly Lys Ser Lys Arg Ala Ile
          50          55          60

gag gat cat ttt gat tac tct cct gag ctt gaa aga aac cta gaa gaa     240
Glu Asp His Phe Asp Tyr Ser Pro Glu Leu Glu Arg Asn Leu Glu Glu
65          70          75          80

aaa gga aaa act gag ctg ctt gaa aaa gtg aaa aag gct tct aac ctg     288
Lys Gly Lys Thr Glu Leu Leu Glu Lys Val Lys Lys Ala Ser Asn Leu
          85          90          95

gct gac att cac tat atc cgc caa aaa gaa cct aaa ggt ctc gga cat     336
Ala Asp Ile His Tyr Ile Arg Gln Lys Glu Pro Lys Gly Leu Gly His
          100         105         110

gct gtc tgg tgc gca cgc aac ttt atc ggc gat gag ccg ttt gcg gta     384
Ala Val Trp Cys Ala Arg Asn Phe Ile Gly Asp Glu Pro Phe Ala Val
          115         120         125

ctg ctt ggt gac gat att gtt cag gct gaa act cca ggg ttg cgc caa     432
Leu Leu Gly Asp Asp Ile Val Gln Ala Glu Thr Pro Gly Leu Arg Gln
          130         135         140

tta atg gat gaa tat gaa aaa aca ctt tct tct att atc ggt gtt cag     480
Leu Met Asp Glu Tyr Glu Lys Thr Leu Ser Ser Ile Ile Gly Val Gln
145          150         155         160

cag gtg ccc gaa gaa gaa aca cac cgc tac ggc att att gac ccg ctg     528
Gln Val Pro Glu Glu Glu Thr His Arg Tyr Gly Ile Ile Asp Pro Leu
          165         170         175

aca agt gaa ggc cgc cgt tat cag gtg aaa aac ttc gtt gaa aaa ccg     576
Thr Ser Glu Gly Arg Arg Tyr Gln Val Lys Asn Phe Val Glu Lys Pro
          180         185         190

cct aaa ggc aca gca cct tct aat ctt gcc atc tta ggc cgt tac gta     624
Pro Lys Gly Thr Ala Pro Ser Asn Leu Ala Ile Leu Gly Arg Tyr Val
          195         200         205

ttc acg cct gag atc ttc atg tat tta gaa gag cag cag gtt ggc gcc     672
Phe Thr Pro Glu Ile Phe Met Tyr Leu Glu Glu Gln Gln Val Gly Ala
          210         215         220

ggc gga gaa att cag ctc aca gac gcc att caa aag ctg aat gaa att     720
Gly Gly Glu Ile Gln Leu Thr Asp Ala Ile Gln Lys Leu Asn Glu Ile
225          230         235         240

caa aga gtg ttt gct tac gat ttt gaa ggc aag cgt tat gat gtt ggt     768
Gln Arg Val Phe Ala Tyr Asp Phe Glu Gly Lys Arg Tyr Asp Val Gly
          245         250         255

gaa aag ctc ggc ttt atc aca aca act ctt gaa ttt gcg atg cag gat     816
Glu Lys Leu Gly Phe Ile Thr Thr Thr Leu Glu Phe Ala Met Gln Asp
          260         265         270

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aaa gag ctt cgc gat cag ctc gtt cca ttt atg gaa ggt tta cta aac      864
Lys Glu Leu Arg Asp Gln Leu Val Pro Phe Met Glu Gly Leu Leu Asn
      275                      280                      285

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aaa gaa gaa atc      876
Lys Glu Glu Ile
      290

```

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<210> SEQ ID NO 22
<211> LENGTH: 292
<212> TYPE: PRT
<213> ORGANISM: Bacillus subtilis

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<400> SEQUENCE: 22

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Met Lys Lys Val Arg Lys Ala Ile Ile Pro Ala Ala Gly Leu Gly Thr
 1          5          10          15
Arg Phe Leu Pro Ala Thr Lys Ala Met Pro Lys Glu Met Leu Pro Ile
      20          25          30
Val Asp Lys Pro Thr Ile Gln Tyr Ile Ile Glu Glu Ala Val Glu Ala
      35          40          45
Gly Ile Glu Asp Ile Ile Ile Val Thr Gly Lys Ser Lys Arg Ala Ile
      50          55          60
Glu Asp His Phe Asp Tyr Ser Pro Glu Leu Glu Arg Asn Leu Glu Glu
      65          70          75          80
Lys Gly Lys Thr Glu Leu Leu Glu Lys Val Lys Lys Ala Ser Asn Leu
      85          90          95
Ala Asp Ile His Tyr Ile Arg Gln Lys Glu Pro Lys Gly Leu Gly His
      100         105         110
Ala Val Trp Cys Ala Arg Asn Phe Ile Gly Asp Glu Pro Phe Ala Val
      115         120         125
Leu Leu Gly Asp Asp Ile Val Gln Ala Glu Thr Pro Gly Leu Arg Gln
      130         135         140
Leu Met Asp Glu Tyr Glu Lys Thr Leu Ser Ser Ile Ile Gly Val Gln
      145         150         155         160
Gln Val Pro Glu Glu Glu Thr His Arg Tyr Gly Ile Ile Asp Pro Leu
      165         170         175
Thr Ser Glu Gly Arg Arg Tyr Gln Val Lys Asn Phe Val Glu Lys Pro
      180         185         190
Pro Lys Gly Thr Ala Pro Ser Asn Leu Ala Ile Leu Gly Arg Tyr Val
      195         200         205
Phe Thr Pro Glu Ile Phe Met Tyr Leu Glu Glu Gln Gln Val Gly Ala
      210         215         220
Gly Gly Glu Ile Gln Leu Thr Asp Ala Ile Gln Lys Leu Asn Glu Ile
      225         230         235         240
Gln Arg Val Phe Ala Tyr Asp Phe Glu Gly Lys Arg Tyr Asp Val Gly
      245         250         255
Glu Lys Leu Gly Phe Ile Thr Thr Thr Leu Glu Phe Ala Met Gln Asp
      260         265         270
Lys Glu Leu Arg Asp Gln Leu Val Pro Phe Met Glu Gly Leu Leu Asn
      275         280         285
Lys Glu Glu Ile
      290

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<210> SEQ ID NO 23
<211> LENGTH: 27
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

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<400> SEQUENCE: 23

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tctagatttt tcgatcataa ggaaggt 27

<210> SEQ ID NO 24
 <211> LENGTH: 49
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis
 <400> SEQUENCE: 24

gttaacgaat tccagctatg taggatccaa tgtccaatag cctttttgt 49

<210> SEQ ID NO 25
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis
 <400> SEQUENCE: 25

aaaaaggctt ctaacctggc 20

<210> SEQ ID NO 26
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis
 <400> SEQUENCE: 26

aaaccgccta aaggcacagc 20

<210> SEQ ID NO 27
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis
 <400> SEQUENCE: 27

gccaggtag aagccttttt 20

<210> SEQ ID NO 28
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis
 <400> SEQUENCE: 28

gctgtgcctt taggcggttt 20

<210> SEQ ID NO 29
 <211> LENGTH: 1368
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(1368)
 <400> SEQUENCE: 29

atg gat aag cgg ttt gca gtt gtt tta gcg gct gga caa gga acg aga 48
 Met Asp Lys Arg Phe Ala Val Val Leu Ala Ala Gly Gln Gly Thr Arg
 1 5 10 15

atg aaa tcg aag ctt tat aaa gtc ctt cat cca gtt tgc ggt aag cct 96
 Met Lys Ser Lys Leu Tyr Lys Val Leu His Pro Val Cys Gly Lys Pro
 20 25 30

atg gta gag cac gtc gtg gac gaa gcc tta aaa tta tct tta tca aag 144
 Met Val Glu His Val Val Asp Glu Ala Leu Lys Leu Ser Leu Ser Lys
 35 40 45

ctt gtc acg att gtc gga cat ggt gcg gaa gaa gtg aaa aag cag ctt 192
 Leu Val Thr Ile Val Gly His Gly Ala Glu Glu Val Lys Lys Gln Leu
 50 55 60

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| | |
|---|------|
| ggt gat aaa agc gag tac gcg ctt caa gca aaa cag ctt ggc act gct Gly Asp Lys Ser Glu Tyr Ala Leu Gln Ala Lys Gln Leu Gly Thr Ala 65 70 75 80 | 240 |
| cat gct gta aaa cag gca cag cca ttt ctt gct gac gaa aaa ggc gtc His Ala Val Lys Gln Ala Gln Pro Phe Leu Ala Asp Glu Lys Gly Val 85 90 95 | 288 |
| aca att gtc att tgc gga gat acg ccg ctt ttg aca gca gag acg atg Thr Ile Val Ile Cys Gly Asp Thr Pro Leu Leu Thr Ala Glu Thr Met 100 105 110 | 336 |
| gaa cag atg ctg aaa gaa cat aca caa aga gaa gcg aaa gct acg att Glu Gln Met Leu Lys Glu His Thr Gln Arg Glu Ala Lys Ala Thr Ile 115 120 125 | 384 |
| tta act gcg gtt gca gaa gat cca act gga tac ggc cgc att att cgc Leu Thr Ala Val Ala Glu Asp Pro Thr Gly Tyr Gly Arg Ile Ile Arg 130 135 140 | 432 |
| agc gaa aac gga gcg gtt caa aaa ata gtt gag cat aag gac gcc tct Ser Glu Asn Gly Ala Val Gln Lys Ile Val Glu His Lys Asp Ala Ser 145 150 155 160 | 480 |
| gaa gaa gaa cgt ctt gta act gag atc aac acc ggt acg tat tgt ttt Glu Glu Glu Arg Leu Val Thr Glu Ile Asn Thr Gly Thr Tyr Cys Phe 165 170 175 | 528 |
| gac aat gaa gcg cta ttt cgg gct att gat cag gtg tct aat gat aat Asp Asn Glu Ala Leu Phe Arg Ala Ile Asp Gln Val Ser Asn Asp Asn 180 185 190 | 576 |
| gca caa ggc gag tat tat ttg ccg gat gtc ata gag att ctt aaa aat Ala Gln Gly Glu Tyr Tyr Leu Pro Asp Val Ile Glu Ile Leu Lys Asn 195 200 205 | 624 |
| gaa ggc gaa act gtt gcc gct tac cag act ggt aat ttc caa gaa acg Glu Gly Glu Thr Val Ala Ala Tyr Gln Thr Gly Asn Phe Gln Glu Thr 210 215 220 | 672 |
| ctc gga gtt aat gat aga gtt gct ctt tct cag gca gaa caa ttt atg Leu Gly Val Asn Asp Arg Val Ala Leu Ser Gln Ala Glu Gln Phe Met 225 230 235 240 | 720 |
| aaa gag cgc att aat aaa cgg cat atg caa aat ggc gtg acg ttg att Lys Glu Arg Ile Asn Lys Arg His Met Gln Asn Gly Val Thr Leu Ile 245 250 255 | 768 |
| gac ccg atg aat acg tat att tct cct gac gct gtt atc gga agc gat Asp Pro Met Asn Thr Tyr Ile Ser Pro Asp Ala Val Ile Gly Ser Asp 260 265 270 | 816 |
| act gtg att tac cct gga act gtg att aaa ggt gag gtg caa atc gga Thr Val Ile Tyr Pro Gly Thr Val Ile Lys Gly Glu Val Gln Ile Gly 275 280 285 | 864 |
| gaa gat acg att att ggc cct cat acg gag att atg aat agt gcc att Glu Asp Thr Ile Ile Gly Pro His Thr Glu Ile Met Asn Ser Ala Ile 290 295 300 | 912 |
| ggc agc cgt acg gtt att aaa caa tcg gta gtc aat cac agt aaa gtg Gly Ser Arg Thr Val Ile Lys Gln Ser Val Val Asn His Ser Lys Val 305 310 315 320 | 960 |
| ggg aat gat gta aac ata gga cct ttt gct cac atc aga cct gat tct Gly Asn Asp Val Asn Ile Gly Pro Phe Ala His Ile Arg Pro Asp Ser 325 330 335 | 1008 |
| gtc atc ggg aat gaa gtg aag atc ggg aat ttt gta gaa att aaa aag Val Ile Gly Asn Glu Val Lys Ile Gly Asn Phe Val Glu Ile Lys Lys 340 345 350 | 1056 |
| act caa ttc gga gac cga agc aag gca tct cat cta agc tat gtc ggc Thr Gln Phe Gly Asp Arg Ser Lys Ala Ser His Leu Ser Tyr Val Gly 355 360 365 | 1104 |
| gat gct gag gta ggc act gat gta aac ctg ggc tgc ggt tca att act Asp Ala Glu Val Gly Thr Asp Val Asn Leu Gly Cys Gly Ser Ile Thr 370 375 380 | 1152 |

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| | |
|---|------|
| gtc aat tat gat gga aag aat aag tat ttg aca aaa att gaa gat ggc | 1200 |
| Val Asn Tyr Asp Gly Lys Asn Lys Tyr Leu Thr Lys Ile Glu Asp Gly | |
| 385 390 395 400 | |
| gcg ttt atc ggc tgc aat tcc aac ttg gtt gcc cct gtc aca gtc gga | 1248 |
| Ala Phe Ile Gly Cys Asn Ser Asn Leu Val Ala Pro Val Thr Val Gly | |
| 405 410 415 | |
| gaa ggc gct tat gtg gcg gca ggt tca act gtt acg gaa gat gta cct | 1296 |
| Glu Gly Ala Tyr Val Ala Ala Gly Ser Thr Val Thr Glu Asp Val Pro | |
| 420 425 430 | |
| gga aaa gca ctt gct att gcc aga gcg aga caa gta aat aaa gac gat | 1344 |
| Gly Lys Ala Leu Ala Ile Ala Arg Ala Arg Gln Val Asn Lys Asp Asp | |
| 435 440 445 | |
| tat gtg aaa aat att cat aaa aaa | 1368 |
| Tyr Val Lys Asn Ile His Lys Lys | |
| 450 455 | |

<210> SEQ ID NO 30
 <211> LENGTH: 456
 <212> TYPE: PRT
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 30

| | |
|---|--|
| Met Asp Lys Arg Phe Ala Val Val Leu Ala Ala Gly Gln Gly Thr Arg | |
| 1 5 10 15 | |
| Met Lys Ser Lys Leu Tyr Lys Val Leu His Pro Val Cys Gly Lys Pro | |
| 20 25 30 | |
| Met Val Glu His Val Val Asp Glu Ala Leu Lys Leu Ser Leu Ser Lys | |
| 35 40 45 | |
| Leu Val Thr Ile Val Gly His Gly Ala Glu Glu Val Lys Lys Gln Leu | |
| 50 55 60 | |
| Gly Asp Lys Ser Glu Tyr Ala Leu Gln Ala Lys Gln Leu Gly Thr Ala | |
| 65 70 75 80 | |
| His Ala Val Lys Gln Ala Gln Pro Phe Leu Ala Asp Glu Lys Gly Val | |
| 85 90 95 | |
| Thr Ile Val Ile Cys Gly Asp Thr Pro Leu Leu Thr Ala Glu Thr Met | |
| 100 105 110 | |
| Glu Gln Met Leu Lys Glu His Thr Gln Arg Glu Ala Lys Ala Thr Ile | |
| 115 120 125 | |
| Leu Thr Ala Val Ala Glu Asp Pro Thr Gly Tyr Gly Arg Ile Ile Arg | |
| 130 135 140 | |
| Ser Glu Asn Gly Ala Val Gln Lys Ile Val Glu His Lys Asp Ala Ser | |
| 145 150 155 160 | |
| Glu Glu Glu Arg Leu Val Thr Glu Ile Asn Thr Gly Thr Tyr Cys Phe | |
| 165 170 175 | |
| Asp Asn Glu Ala Leu Phe Arg Ala Ile Asp Gln Val Ser Asn Asp Asn | |
| 180 185 190 | |
| Ala Gln Gly Glu Tyr Tyr Leu Pro Asp Val Ile Glu Ile Leu Lys Asn | |
| 195 200 205 | |
| Glu Gly Glu Thr Val Ala Ala Tyr Gln Thr Gly Asn Phe Gln Glu Thr | |
| 210 215 220 | |
| Leu Gly Val Asn Asp Arg Val Ala Leu Ser Gln Ala Glu Gln Phe Met | |
| 225 230 235 240 | |
| Lys Glu Arg Ile Asn Lys Arg His Met Gln Asn Gly Val Thr Leu Ile | |
| 245 250 255 | |
| Asp Pro Met Asn Thr Tyr Ile Ser Pro Asp Ala Val Ile Gly Ser Asp | |
| 260 265 270 | |
| Thr Val Ile Tyr Pro Gly Thr Val Ile Lys Gly Glu Val Gln Ile Gly | |

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| 275 | 280 | 285 |
|--|-----|-----|
| Glu Asp Thr Ile Ile Gly Pro His Thr Glu Ile Met Asn Ser Ala Ile 290 295 300 | | |
| Gly Ser Arg Thr Val Ile Lys Gln Ser Val Val Asn His Ser Lys Val 305 310 315 320 | | |
| Gly Asn Asp Val Asn Ile Gly Pro Phe Ala His Ile Arg Pro Asp Ser 325 330 335 | | |
| Val Ile Gly Asn Glu Val Lys Ile Gly Asn Phe Val Glu Ile Lys Lys 340 345 350 | | |
| Thr Gln Phe Gly Asp Arg Ser Lys Ala Ser His Leu Ser Tyr Val Gly 355 360 365 | | |
| Asp Ala Glu Val Gly Thr Asp Val Asn Leu Gly Cys Gly Ser Ile Thr 370 375 380 | | |
| Val Asn Tyr Asp Gly Lys Asn Lys Tyr Leu Thr Lys Ile Glu Asp Gly 385 390 395 400 | | |
| Ala Phe Ile Gly Cys Asn Ser Asn Leu Val Ala Pro Val Thr Val Gly 405 410 415 | | |
| Glu Gly Ala Tyr Val Ala Ala Gly Ser Thr Val Thr Glu Asp Val Pro 420 425 430 | | |
| Gly Lys Ala Leu Ala Ile Ala Arg Ala Arg Gln Val Asn Lys Asp Asp 435 440 445 | | |
| Tyr Val Lys Asn Ile His Lys Lys 450 455 | | |

<210> SEQ ID NO 31
 <211> LENGTH: 26
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 31

ggatcctttc tatggataaa agggat

26

<210> SEQ ID NO 32
 <211> LENGTH: 31
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 32

gttaacagga ttatTTTTta tgaatatttt t

31

<210> SEQ ID NO 33
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 33

cagagacgat ggaacagatg

20

<210> SEQ ID NO 34
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 34

ggagttaatg atagagttgc

20

<210> SEQ ID NO 35
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

-continued

<400> SEQUENCE: 35

gaagatcggg aattttgtag 20

<210> SEQ ID NO 36
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 36

catctgttcc atcgtctctg 20

<210> SEQ ID NO 37
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 37

gcaactctat cattaactcc 20

<210> SEQ ID NO 38
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 38

ctacaaaatt cccgatcttc 20

<210> SEQ ID NO 39
 <211> LENGTH: 54
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 39

gtgtcggaac attcattaca tgcttaagca cccgctgtcc ttcttggtat ctcc 54

<210> SEQ ID NO 40
 <211> LENGTH: 1203
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus equisimilis
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(1203)

<400> SEQUENCE: 40

gtg aaa att tct gta gca ggc tca gga tat gtc ggc cta tcc ttg agt 48
 Val Lys Ile Ser Val Ala Gly Ser Gly Tyr Val Gly Leu Ser Leu Ser
 1 5 10 15

att tta ctg gca caa cat aat gac gtc act gtt gtt gat att att gat 96
 Ile Leu Leu Ala Gln His Asn Asp Val Thr Val Val Asp Ile Ile Asp
 20 25 30

gaa aag gtg aga ttg atc aat caa ggc ata tct cca atc aag gat gct 144
 Glu Lys Val Arg Leu Ile Asn Gln Gly Ile Ser Pro Ile Lys Asp Ala
 35 40 45

gat att gag gag tat tta aaa aat gcg ccg cta aat ctc aca gcg acc 192
 Asp Ile Glu Glu Tyr Leu Lys Asn Ala Pro Leu Asn Leu Thr Ala Thr
 50 55 60

ctt gat ggc gca agc gct tat agc aat gca gac ctt att atc att gct 240
 Leu Asp Gly Ala Ser Ala Tyr Ser Asn Ala Asp Leu Ile Ile Ile Ala
 65 70 75 80

act ccg aca aat tat gac agc gaa cgc aac tac ttt gac aca agg cat 288
 Thr Pro Thr Asn Tyr Asp Ser Glu Arg Asn Tyr Phe Asp Thr Arg His
 85 90 95

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| | |
|---|------|
| ggt gaa gag gtc att gag cag gtc cta gac cta aat gcg tca gca acc | 336 |
| Val Glu Glu Val Ile Glu Gln Val Leu Asp Leu Asn Ala Ser Ala Thr | |
| 100 105 110 | |
| att att atc aaa tca acc ata cca cta ggc ttt atc aag cat gtt agg | 384 |
| Ile Ile Ile Lys Ser Thr Ile Pro Leu Gly Phe Ile Lys His Val Arg | |
| 115 120 125 | |
| gaa aaa tac cag aca gat cgt att att ttt agc cca gaa ttt tta aga | 432 |
| Glu Lys Tyr Gln Thr Asp Arg Ile Ile Phe Ser Pro Glu Phe Leu Arg | |
| 130 135 140 | |
| gaa tca aaa gcc tta tac gat aac ctt tac cca agt cgg atc att gtt | 480 |
| Glu Ser Lys Ala Leu Tyr Asp Asn Leu Tyr Pro Ser Arg Ile Ile Val | |
| 145 150 155 160 | |
| tct tat gaa aag gac gac tca cca agg gtt att cag gct gct aaa gcc | 528 |
| Ser Tyr Glu Lys Asp Asp Ser Pro Arg Val Ile Gln Ala Ala Lys Ala | |
| 165 170 175 | |
| ttt gct ggt ctt tta aag gaa gga gcc aaa agc aag gat act ccg gtc | 576 |
| Phe Ala Gly Leu Leu Lys Glu Gly Ala Lys Ser Lys Asp Thr Pro Val | |
| 180 185 190 | |
| tta ttt atg ggc tca cag gag gct gag gcg gtc aag cta ttt gcg aat | 624 |
| Leu Phe Met Gly Ser Gln Glu Ala Glu Ala Val Lys Leu Phe Ala Asn | |
| 195 200 205 | |
| acc ttt ttg gct atg cgg gtg tct tac ttt aat gaa tta gac acc tat | 672 |
| Thr Phe Leu Ala Met Arg Val Ser Tyr Phe Asn Glu Leu Asp Thr Tyr | |
| 210 215 220 | |
| tcc gaa agc aag ggt cta gat gct cag cgc gtg att gaa gga gtc tgt | 720 |
| Ser Glu Ser Lys Gly Leu Asp Ala Gln Arg Val Ile Glu Gly Val Cys | |
| 225 230 235 240 | |
| cat gat cag cgc att ggt aac cat tac aat aac cct tcc ttt gga tat | 768 |
| His Asp Gln Arg Ile Gly Asn His Tyr Asn Asn Pro Ser Phe Gly Tyr | |
| 245 250 255 | |
| ggc ggc tat tgc ctg cca aag gac agc aaa cag ctg ttg gca aat tat | 816 |
| Gly Gly Tyr Cys Leu Pro Lys Asp Ser Lys Gln Leu Leu Ala Asn Tyr | |
| 260 265 270 | |
| aga ggc att ccc cag tcc ttg atg tca gcg att gtt gag tcc aac aag | 864 |
| Arg Gly Ile Pro Gln Ser Leu Met Ser Ala Ile Val Glu Ser Asn Lys | |
| 275 280 285 | |
| ata cga aaa tcc tat tta gct gaa caa ata tta gac aga gcc tct agt | 912 |
| Ile Arg Lys Ser Tyr Leu Ala Glu Gln Ile Leu Asp Arg Ala Ser Ser | |
| 290 295 300 | |
| caa aag cag gct ggt gta cca tta acg att ggc ttt tac cgc ttg att | 960 |
| Gln Lys Gln Ala Gly Val Pro Leu Thr Ile Gly Phe Tyr Arg Leu Ile | |
| 305 310 315 320 | |
| atg aaa agc aac tct gat aat ttc cga gaa agc gcc att aaa gat att | 1008 |
| Met Lys Ser Asn Ser Asp Asn Phe Arg Glu Ser Ala Ile Lys Asp Ile | |
| 325 330 335 | |
| att gat atc atc aac gac tat ggg gtt aat att gtc att tac gaa ccc | 1056 |
| Ile Asp Ile Ile Asn Asp Tyr Gly Val Asn Ile Val Ile Tyr Glu Pro | |
| 340 345 350 | |
| atg ctt ggc gag gat att ggc tac agg gtt gtc aag gac tta gag cag | 1104 |
| Met Leu Gly Glu Asp Ile Gly Tyr Arg Val Val Lys Asp Leu Glu Gln | |
| 355 360 365 | |
| ttc aaa aac gag tct aca atc att gtg tca aat cgc ttt gag gac gac | 1152 |
| Phe Lys Asn Glu Ser Thr Ile Ile Val Ser Asn Arg Phe Glu Asp Asp | |
| 370 375 380 | |
| cta gga gat gtc att gat aag gtt tat acg aga gat gtc ttt gga aga | 1200 |
| Leu Gly Asp Val Ile Asp Lys Val Tyr Thr Arg Asp Val Phe Gly Arg | |
| 385 390 395 400 | |
| gac | 1203 |
| Asp | |

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<210> SEQ ID NO 41
<211> LENGTH: 401
<212> TYPE: PRT
<213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 41

Val Lys Ile Ser Val Ala Gly Ser Gly Tyr Val Gly Leu Ser Leu Ser
1      5      10      15
Ile Leu Leu Ala Gln His Asn Asp Val Thr Val Val Asp Ile Ile Asp
20      25      30
Glu Lys Val Arg Leu Ile Asn Gln Gly Ile Ser Pro Ile Lys Asp Ala
35      40      45
Asp Ile Glu Glu Tyr Leu Lys Asn Ala Pro Leu Asn Leu Thr Ala Thr
50      55      60
Leu Asp Gly Ala Ser Ala Tyr Ser Asn Ala Asp Leu Ile Ile Ile Ala
65      70      75      80
Thr Pro Thr Asn Tyr Asp Ser Glu Arg Asn Tyr Phe Asp Thr Arg His
85      90      95
Val Glu Glu Val Ile Glu Gln Val Leu Asp Leu Asn Ala Ser Ala Thr
100     105     110
Ile Ile Ile Lys Ser Thr Ile Pro Leu Gly Phe Ile Lys His Val Arg
115     120     125
Glu Lys Tyr Gln Thr Asp Arg Ile Ile Phe Ser Pro Glu Phe Leu Arg
130     135     140
Glu Ser Lys Ala Leu Tyr Asp Asn Leu Tyr Pro Ser Arg Ile Ile Val
145     150     155     160
Ser Tyr Glu Lys Asp Asp Ser Pro Arg Val Ile Gln Ala Ala Lys Ala
165     170     175
Phe Ala Gly Leu Leu Lys Glu Gly Ala Lys Ser Lys Asp Thr Pro Val
180     185     190
Leu Phe Met Gly Ser Gln Glu Ala Glu Ala Val Lys Leu Phe Ala Asn
195     200     205
Thr Phe Leu Ala Met Arg Val Ser Tyr Phe Asn Glu Leu Asp Thr Tyr
210     215     220
Ser Glu Ser Lys Gly Leu Asp Ala Gln Arg Val Ile Glu Gly Val Cys
225     230     235     240
His Asp Gln Arg Ile Gly Asn His Tyr Asn Asn Pro Ser Phe Gly Tyr
245     250     255
Gly Gly Tyr Cys Leu Pro Lys Asp Ser Lys Gln Leu Leu Ala Asn Tyr
260     265     270
Arg Gly Ile Pro Gln Ser Leu Met Ser Ala Ile Val Glu Ser Asn Lys
275     280     285
Ile Arg Lys Ser Tyr Leu Ala Glu Gln Ile Leu Asp Arg Ala Ser Ser
290     295     300
Gln Lys Gln Ala Gly Val Pro Leu Thr Ile Gly Phe Tyr Arg Leu Ile
305     310     315     320
Met Lys Ser Asn Ser Asp Asn Phe Arg Glu Ser Ala Ile Lys Asp Ile
325     330     335
Ile Asp Ile Ile Asn Asp Tyr Gly Val Asn Ile Val Ile Tyr Glu Pro
340     345     350
Met Leu Gly Glu Asp Ile Gly Tyr Arg Val Val Lys Asp Leu Glu Gln
355     360     365
Phe Lys Asn Glu Ser Thr Ile Ile Val Ser Asn Arg Phe Glu Asp Asp
370     375     380
Leu Gly Asp Val Ile Asp Lys Val Tyr Thr Arg Asp Val Phe Gly Arg

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| 385 | 390 | 395 | 400 | | | | | | | | | | | | | |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Asp | | | | | | | | | | | | | | | | |
| <210> SEQ ID NO 42 | | | | | | | | | | | | | | | | |
| <211> LENGTH: 900 | | | | | | | | | | | | | | | | |
| <212> TYPE: DNA | | | | | | | | | | | | | | | | |
| <213> ORGANISM: Streptococcus equisimilis | | | | | | | | | | | | | | | | |
| <220> FEATURE: | | | | | | | | | | | | | | | | |
| <221> NAME/KEY: CDS | | | | | | | | | | | | | | | | |
| <222> LOCATION: (1)..(900) | | | | | | | | | | | | | | | | |
| <400> SEQUENCE: 42 | | | | | | | | | | | | | | | | |
| atg | aca | aag | gtc | aga | aaa | gcc | att | atc | cca | gcc | gcc | ggc | cta | ggc | act | 48 |
| Met | Thr | Lys | Val | Arg | Lys | Ala | Ile | Ile | Pro | Ala | Ala | Gly | Leu | Gly | Thr | |
| 1 | | | | 5 | | | | | 10 | | | | | 15 | | |
| cgc | ttc | cta | ccc | gcc | acc | aag | gca | ctg | gcc | aag | gaa | atg | ctc | cca | atc | 96 |
| Arg | Phe | Leu | Pro | Ala | Thr | Lys | Ala | Leu | Ala | Lys | Glu | Met | Leu | Pro | Ile | |
| | | | 20 | | | | | 25 | | | | | 30 | | | |
| gtc | gat | aag | cca | acc | att | caa | ttc | atc | gtc | gag | gaa | gct | cta | aag | gcc | 144 |
| Val | Asp | Lys | Pro | Thr | Ile | Gln | Phe | Ile | Val | Glu | Glu | Ala | Leu | Lys | Ala | |
| | | 35 | | | | | 40 | | | | | 45 | | | | |
| ggt | atc | gag | gag | att | ctt | gtc | gtc | acc | ggc | aag | gcc | aaa | cgc | tct | att | 192 |
| Gly | Ile | Glu | Glu | Ile | Leu | Val | Val | Thr | Gly | Lys | Ala | Lys | Arg | Ser | Ile | |
| | 50 | | | | | 55 | | | | | 60 | | | | | |
| gaa | gac | cac | ttt | gac | tcc | aac | ttc | gag | ctc | gaa | tac | aat | ctc | caa | gcc | 240 |
| Glu | Asp | His | Phe | Asp | Ser | Asn | Phe | Glu | Leu | Glu | Tyr | Asn | Leu | Gln | Ala | |
| 65 | | | | | 70 | | | | | 75 | | | | | 80 | |
| aag | ggc | aaa | acc | gag | ctg | ctc | aag | ctc | ggt | gat | gag | acc | act | gcc | atc | 288 |
| Lys | Gly | Lys | Thr | Glu | Leu | Leu | Lys | Leu | Val | Asp | Glu | Thr | Thr | Ala | Ile | |
| | | | 85 | | | | | | 90 | | | | | 95 | | |
| aac | ctg | cac | ttc | att | cgt | cag | agc | cac | cct | aga | gga | cta | ggg | gac | gct | 336 |
| Asn | Leu | His | Phe | Ile | Arg | Gln | Ser | His | Pro | Arg | Gly | Leu | Gly | Asp | Ala | |
| | | | 100 | | | | | 105 | | | | | | 110 | | |
| gtc | ctc | cag | gcc | aag | gcc | ttt | gtg | ggc | aat | gag | ccc | ttt | gtg | gtc | atg | 384 |
| Val | Leu | Gln | Ala | Lys | Ala | Phe | Val | Gly | Asn | Glu | Pro | Phe | Val | Val | Met | |
| | | 115 | | | | | 120 | | | | | 125 | | | | |
| ctg | ggg | gat | gac | ctc | atg | gat | att | acc | aat | cct | agt | gcc | aag | ccc | ttg | 432 |
| Leu | Gly | Asp | Asp | Leu | Met | Asp | Ile | Thr | Asn | Pro | Ser | Ala | Lys | Pro | Leu | |
| | 130 | | | | | 135 | | | | | 140 | | | | | |
| gcc | aag | cag | ctc | att | gag | gat | tat | gat | tgc | aca | cac | gcc | tca | acg | att | 480 |
| Ala | Lys | Gln | Leu | Ile | Glu | Asp | Tyr | Asp | Cys | Thr | His | Ala | Ser | Thr | Ile | |
| 145 | | | | | 150 | | | | | 155 | | | | | 160 | |
| gca | gtg | atg | agg | gtg | ccg | cat | gag | gag | ggt | tcc | aat | tat | ggc | gtg | att | 528 |
| Ala | Val | Met | Arg | Val | Pro | His | Glu | Glu | Val | Ser | Asn | Tyr | Gly | Val | Ile | |
| | | | 165 | | | | | | 170 | | | | | 175 | | |
| gca | ccg | caa | ggg | aag | gct | ggt | aag | ggc | ttg | tat | agt | gtg | gag | acc | ttt | 576 |
| Ala | Pro | Gln | Gly | Lys | Ala | Val | Lys | Gly | Leu | Tyr | Ser | Val | Glu | Thr | Phe | |
| | | | 180 | | | | | 185 | | | | | 190 | | | |
| ggt | gag | aag | cca | agt | cca | gat | gag | gca | ccg | agt | gac | tta | gcg | att | att | 624 |
| Val | Glu | Lys | Pro | Ser | Pro | Asp | Glu | Ala | Pro | Ser | Asp | Leu | Ala | Ile | Ile | |
| | | 195 | | | | | 200 | | | | | 205 | | | | |
| ggt | cga | tat | ttg | ttg | acg | cct | gag | att | ttt | gcc | ata | ttg | gag | aat | cag | 672 |
| Gly | Arg | Tyr | Leu | Leu | Thr | Pro | Glu | Ile | Phe | Ala | Ile | Leu | Glu | Asn | Gln | |
| | 210 | | | | | 215 | | | | | 220 | | | | | |
| gcg | cct | ggg | gct | ggc | aat | gag | gta | cag | cta | gcc | gat | gcg | att | gac | aag | 720 |
| Ala | Pro | Gly | Ala | Gly | Asn | Glu | Val | Gln | Leu | Ala | Asp | Ala | Ile | Asp | Lys | |
| 225 | | | | | 230 | | | | | 235 | | | | | 240 | |
| ctc | aac | aag | act | cag | cgg | ggt | ttt | gcg | agg | gag | ttt | aag | gga | gag | cgg | 768 |
| Leu | Asn | Lys | Thr | Gln | Arg | Val | Phe | Ala | Arg | Glu | Phe | Lys | Gly | Glu | Arg | |
| | | | 245 | | | | | | 250 | | | | | 255 | | |
| tat | gat | ggt | ggg | gac | aag | ttt | ggc | ttt | atg | aag | acc | tca | ctt | gac | tat | 816 |

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Tyr Asp Val Gly Asp Lys Phe Gly Phe Met Lys Thr Ser Leu Asp Tyr
      260                265                270
gct ctc aag cac cct cag gtc aag gac gac ctc act gac tac att ata      864
Ala Leu Lys His Pro Gln Val Lys Asp Asp Leu Thr Asp Tyr Ile Ile
      275                280                285
aag ctc agt aag caa ctg aac aag gac gtt aaa aaa                        900
Lys Leu Ser Lys Gln Leu Asn Lys Asp Val Lys Lys
      290                295                300

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<210> SEQ ID NO 43
<211> LENGTH: 300
<212> TYPE: PRT
<213> ORGANISM: Streptococcus equisimilis

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<400> SEQUENCE: 43

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Met Thr Lys Val Arg Lys Ala Ile Ile Pro Ala Ala Gly Leu Gly Thr
 1                5                10                15
Arg Phe Leu Pro Ala Thr Lys Ala Leu Ala Lys Glu Met Leu Pro Ile
      20                25                30
Val Asp Lys Pro Thr Ile Gln Phe Ile Val Glu Glu Ala Leu Lys Ala
      35                40                45
Gly Ile Glu Glu Ile Leu Val Val Thr Gly Lys Ala Lys Arg Ser Ile
      50                55                60
Glu Asp His Phe Asp Ser Asn Phe Glu Leu Glu Tyr Asn Leu Gln Ala
      65                70                75                80
Lys Gly Lys Thr Glu Leu Leu Lys Leu Val Asp Glu Thr Thr Ala Ile
      85                90                95
Asn Leu His Phe Ile Arg Gln Ser His Pro Arg Gly Leu Gly Asp Ala
      100               105               110
Val Leu Gln Ala Lys Ala Phe Val Gly Asn Glu Pro Phe Val Val Met
      115               120               125
Leu Gly Asp Asp Leu Met Asp Ile Thr Asn Pro Ser Ala Lys Pro Leu
      130               135               140
Ala Lys Gln Leu Ile Glu Asp Tyr Asp Cys Thr His Ala Ser Thr Ile
      145               150               155               160
Ala Val Met Arg Val Pro His Glu Glu Val Ser Asn Tyr Gly Val Ile
      165               170               175
Ala Pro Gln Gly Lys Ala Val Lys Gly Leu Tyr Ser Val Glu Thr Phe
      180               185               190
Val Glu Lys Pro Ser Pro Asp Glu Ala Pro Ser Asp Leu Ala Ile Ile
      195               200               205
Gly Arg Tyr Leu Leu Thr Pro Glu Ile Phe Ala Ile Leu Glu Asn Gln
      210               215               220
Ala Pro Gly Ala Gly Asn Glu Val Gln Leu Ala Asp Ala Ile Asp Lys
      225               230               235               240
Leu Asn Lys Thr Gln Arg Val Phe Ala Arg Glu Phe Lys Gly Glu Arg
      245               250               255
Tyr Asp Val Gly Asp Lys Phe Gly Phe Met Lys Thr Ser Leu Asp Tyr
      260                265                270
Ala Leu Lys His Pro Gln Val Lys Asp Asp Leu Thr Asp Tyr Ile Ile
      275                280                285
Lys Leu Ser Lys Gln Leu Asn Lys Asp Val Lys Lys
      290                295                300

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<210> SEQ ID NO 44
<211> LENGTH: 1380
<212> TYPE: DNA

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<213> ORGANISM: Streptococcus equisimilis
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(1380)

<400> SEQUENCE: 44

atg aaa aac tac gcc att atc cta gca gct gga aag gga acc cgc atg      48
Met Lys Asn Tyr Ala Ile Ile Leu Ala Ala Gly Lys Gly Thr Arg Met
1                               5                               10                               15

aat tca ggg ctt tcc aag gtg ctg cac aag gta tca ggc cta agc atg      96
Asn Ser Gly Leu Ser Lys Val Leu His Lys Val Ser Gly Leu Ser Met
20                              25                              30

ctg gag cat gtc ctc aag agc gtc tca gcc cta gct cct caa aag caa     144
Leu Glu His Val Leu Lys Ser Val Ser Ala Leu Ala Pro Gln Lys Gln
35                              40                              45

ctc aca gtg atc ggt cat cag gca gag caa gta cgt gcc gtc cta ggt     192
Leu Thr Val Ile Gly His Gln Ala Glu Gln Val Arg Ala Val Leu Gly
50                              55                              60

gat caa tta ctg aca gtg gtg caa gag gag cag cta gga aca ggc cat     240
Asp Gln Leu Leu Thr Val Val Gln Glu Glu Gln Leu Gly Thr Gly His
65                              70                              75                              80

gca gtc atg atg gca gaa gag gag cta tct ggc tta gaa ggg cag acc     288
Ala Val Met Met Ala Glu Glu Glu Leu Ser Gly Leu Glu Gly Gln Thr
85                              90                              95

cta gtg att gca ggt gac acc ccc ttg atc aga gga gaa agc ctc aag     336
Leu Val Ile Ala Gly Asp Thr Pro Leu Ile Arg Gly Glu Ser Leu Lys
100                             105                             110

gct ctg cta gac tat cat atc aga gaa aag aat gtg gca acc att ctc     384
Ala Leu Leu Asp Tyr His Ile Arg Glu Lys Asn Val Ala Thr Ile Leu
115                             120                             125

aca gcc aat gcc aag gat ccc ttt ggc tac ggc cga atc att cgc aat     432
Thr Ala Asn Ala Lys Asp Pro Phe Gly Tyr Gly Arg Ile Ile Arg Asn
130                             135                             140

gca gca gga gag gtg gtc aac atc gtt gaa caa aag gac gct aat gag     480
Ala Ala Gly Glu Val Val Asn Ile Val Glu Gln Lys Asp Ala Asn Glu
145                             150                             155                             160

gca gag caa gag gtc aag gag atc aac aca ggg acc tat atc ttt gac     528
Ala Glu Gln Glu Val Lys Glu Ile Asn Thr Gly Thr Tyr Ile Phe Asp
165                             170                             175

aat aag cgc ctc ttt gag gct cta aag cat ctc acg act gat aat gcc     576
Asn Lys Arg Leu Phe Glu Ala Leu Lys His Leu Thr Thr Asp Asn Ala
180                             185                             190

caa ggg gaa tat tac cta acc gat gtg atc agt att ttc aag gcc agc     624
Gln Gly Glu Tyr Tyr Leu Thr Asp Val Ile Ser Ile Phe Lys Ala Ser
195                             200                             205

caa gaa aag gtt gga gct tac ctg ctg aag gat ttt gat gaa agc cta     672
Gln Glu Lys Val Gly Ala Tyr Leu Leu Lys Asp Phe Asp Glu Ser Leu
210                             215                             220

ggg gtt aat gat cgc cta gct cta gcc cag gct gag gtg atc atg cag     720
Gly Val Asn Asp Arg Leu Ala Leu Ala Gln Ala Glu Val Ile Met Gln
225                             230                             235                             240

gag cgg atc aac aag cag cac atg ctt aat ggg gtg acc ctg caa aac     768
Glu Arg Ile Asn Lys Gln His Met Leu Asn Gly Val Thr Leu Gln Asn
245                             250                             255

cct gca gct acc tat atc gaa agc agt gta gag att gcg ccg gac gtc     816
Pro Ala Ala Thr Tyr Ile Glu Ser Ser Val Glu Ile Ala Pro Asp Val
260                             265                             270

ttg att gaa gct aat gtg acc cta aag gga cag act aga att ggc agc     864
Leu Ile Glu Ala Asn Val Thr Leu Lys Gly Gln Thr Arg Ile Gly Ser
275                             280                             285

aga agt gtt ata acc aat ggg agc tat atc ctt gat tca agg ctt ggt     912

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| | | | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|--|
| Arg | Ser | Val | Ile | Thr | Asn | Gly | Ser | Tyr | Ile | Leu | Asp | Ser | Arg | Leu | Gly | | |
| 290 | | | | | | 295 | | | | | 300 | | | | | | |
| gag | ggc | gta | gtg | gtg | agc | cag | tca | gtg | att | gag | ggc | tca | gtc | cta | gca | 960 | |
| Glu | Gly | Val | Val | Val | Ser | Gln | Ser | Val | Ile | Glu | Gly | Ser | Val | Leu | Ala | | |
| 305 | | | | | 310 | | | | 315 | | | | | 320 | | | |
| gat | ggt | gtg | aca | gta | ggg | ccc | tat | gca | cac | att | cgc | ccg | gac | tct | cag | 1008 | |
| Asp | Gly | Val | Thr | Val | Gly | Pro | Tyr | Ala | His | Ile | Arg | Pro | Asp | Ser | Gln | | |
| | | | | 325 | | | | | 330 | | | | | 335 | | | |
| ctc | gat | gag | tgt | gtt | cat | att | ggg | aac | ttt | gta | gag | gtt | aag | ggg | tct | 1056 | |
| Leu | Asp | Glu | Cys | Val | His | Ile | Gly | Asn | Phe | Val | Glu | Val | Lys | Gly | Ser | | |
| | | | 340 | | | | 345 | | | | | | 350 | | | | |
| cat | cta | ggg | gcc | aat | acc | aag | gca | ggg | cat | ttg | act | tat | ctg | ggg | aat | 1104 | |
| His | Leu | Gly | Ala | Asn | Thr | Lys | Ala | Gly | His | Leu | Thr | Tyr | Leu | Gly | Asn | | |
| | | 355 | | | | 360 | | | | | | 365 | | | | | |
| gcc | gag | att | ggc | tca | gag | ggt | aat | att | ggt | gca | gga | agc | att | acg | gtt | 1152 | |
| Ala | Glu | Ile | Gly | Ser | Glu | Val | Asn | Ile | Gly | Ala | Gly | Ser | Ile | Thr | Val | | |
| | 370 | | | | | 375 | | | | | 380 | | | | | | |
| aat | tat | gat | ggt | caa | cgg | aaa | tac | cag | aca | gtg | att | ggc | gat | cac | gct | 1200 | |
| Asn | Tyr | Asp | Gly | Gln | Arg | Lys | Tyr | Gln | Thr | Val | Ile | Gly | Asp | His | Ala | | |
| 385 | | | | | 390 | | | | | 395 | | | | 400 | | | |
| ttt | att | ggg | agt | cat | tcg | act | ttg | ata | gct | ccg | gta | gag | gtt | ggg | gag | 1248 | |
| Phe | Ile | Gly | Ser | His | Ser | Thr | Leu | Ile | Ala | Pro | Val | Glu | Val | Gly | Glu | | |
| | | | | 405 | | | | | 410 | | | | | 415 | | | |
| aat | gct | tta | aca | gca | gca | ggg | tct | acg | ata | gcc | cag | tcg | gtg | cca | gca | 1296 | |
| Asn | Ala | Leu | Thr | Ala | Ala | Gly | Ser | Thr | Ile | Ala | Gln | Ser | Val | Pro | Ala | | |
| | | | 420 | | | | | 425 | | | | | 430 | | | | |
| gac | agt | gtg | gct | ata | ggg | cgt | agc | cgt | cag | gtg | gtg | aag | gaa | ggc | tat | 1344 | |
| Asp | Ser | Val | Ala | Ile | Gly | Arg | Ser | Arg | Gln | Val | Val | Lys | Glu | Gly | Tyr | | |
| | | 435 | | | | 440 | | | | | | 445 | | | | | |
| gcc | aag | agg | cta | cca | cat | cac | ccg | gat | cag | ccc | cag | | | | | 1380 | |
| Ala | Lys | Arg | Leu | Pro | His | His | Pro | Asp | Gln | Pro | Gln | | | | | | |
| | 450 | | | | | 455 | | | | | 460 | | | | | | |

<210> SEQ ID NO 45

<211> LENGTH: 460

<212> TYPE: PRT

<213> ORGANISM: Streptococcus equisimilis

<400> SEQUENCE: 45

| | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Met | Lys | Asn | Tyr | Ala | Ile | Ile | Leu | Ala | Ala | Gly | Lys | Gly | Thr | Arg | Met |
| 1 | | | | 5 | | | | | 10 | | | | | 15 | |
| Asn | Ser | Gly | Leu | Ser | Lys | Val | Leu | His | Lys | Val | Ser | Gly | Leu | Ser | Met |
| | | 20 | | | | | | 25 | | | | | 30 | | |
| Leu | Glu | His | Val | Leu | Lys | Ser | Val | Ser | Ala | Leu | Ala | Pro | Gln | Lys | Gln |
| | | 35 | | | | | 40 | | | | | 45 | | | |
| Leu | Thr | Val | Ile | Gly | His | Gln | Ala | Glu | Gln | Val | Arg | Ala | Val | Leu | Gly |
| | 50 | | | | | 55 | | | | | 60 | | | | |
| Asp | Gln | Leu | Leu | Thr | Val | Val | Gln | Glu | Glu | Gln | Leu | Gly | Thr | Gly | His |
| 65 | | | | | 70 | | | | | 75 | | | | | 80 |
| Ala | Val | Met | Met | Ala | Glu | Glu | Glu | Leu | Ser | Gly | Leu | Glu | Gly | Gln | Thr |
| | | | | 85 | | | | | 90 | | | | | 95 | |
| Leu | Val | Ile | Ala | Gly | Asp | Thr | Pro | Leu | Ile | Arg | Gly | Glu | Ser | Leu | Lys |
| | | | 100 | | | | | 105 | | | | | 110 | | |
| Ala | Leu | Leu | Asp | Tyr | His | Ile | Arg | Glu | Lys | Asn | Val | Ala | Thr | Ile | Leu |
| | | 115 | | | | | 120 | | | | | 125 | | | |
| Thr | Ala | Asn | Ala | Lys | Asp | Pro | Phe | Gly | Tyr | Gly | Arg | Ile | Ile | Arg | Asn |
| | 130 | | | | | 135 | | | | | 140 | | | | |
| Ala | Ala | Gly | Glu | Val | Val | Asn | Ile | Val | Glu | Gln | Lys | Asp | Ala | Asn | Glu |
| 145 | | | | | 150 | | | | | | 155 | | | | 160 |

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Ala Glu Gln Glu Val Lys Glu Ile Asn Thr Gly Thr Tyr Ile Phe Asp
 165 170 175

Asn Lys Arg Leu Phe Glu Ala Leu Lys His Leu Thr Thr Asp Asn Ala
 180 185 190

Gln Gly Glu Tyr Tyr Leu Thr Asp Val Ile Ser Ile Phe Lys Ala Ser
 195 200 205

Gln Glu Lys Val Gly Ala Tyr Leu Leu Lys Asp Phe Asp Glu Ser Leu
 210 215 220

Gly Val Asn Asp Arg Leu Ala Leu Ala Gln Ala Glu Val Ile Met Gln
 225 230 235 240

Glu Arg Ile Asn Lys Gln His Met Leu Asn Gly Val Thr Leu Gln Asn
 245 250 255

Pro Ala Ala Thr Tyr Ile Glu Ser Ser Val Glu Ile Ala Pro Asp Val
 260 265 270

Leu Ile Glu Ala Asn Val Thr Leu Lys Gly Gln Thr Arg Ile Gly Ser
 275 280 285

Arg Ser Val Ile Thr Asn Gly Ser Tyr Ile Leu Asp Ser Arg Leu Gly
 290 295 300

Glu Gly Val Val Val Ser Gln Ser Val Ile Glu Gly Ser Val Leu Ala
 305 310 315 320

Asp Gly Val Thr Val Gly Pro Tyr Ala His Ile Arg Pro Asp Ser Gln
 325 330 335

Leu Asp Glu Cys Val His Ile Gly Asn Phe Val Glu Val Lys Gly Ser
 340 345 350

His Leu Gly Ala Asn Thr Lys Ala Gly His Leu Thr Tyr Leu Gly Asn
 355 360 365

Ala Glu Ile Gly Ser Glu Val Asn Ile Gly Ala Gly Ser Ile Thr Val
 370 375 380

Asn Tyr Asp Gly Gln Arg Lys Tyr Gln Thr Val Ile Gly Asp His Ala
 385 390 395 400

Phe Ile Gly Ser His Ser Thr Leu Ile Ala Pro Val Glu Val Gly Glu
 405 410 415

Asn Ala Leu Thr Ala Ala Gly Ser Thr Ile Ala Gln Ser Val Pro Ala
 420 425 430

Asp Ser Val Ala Ile Gly Arg Ser Arg Gln Val Val Lys Glu Gly Tyr
 435 440 445

Ala Lys Arg Leu Pro His His Pro Asp Gln Pro Gln
 450 455 460

<210> SEQ ID NO 46
 <211> LENGTH: 29
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 46

gcggccgagg tacctgtgtt acacctgtt

29

<210> SEQ ID NO 47
 <211> LENGTH: 38
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 47

gtcaagctta attctcatgt ttgacagctt atcatcgg

38

<210> SEQ ID NO 48

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<211> LENGTH: 18
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 48

catgggagag acctttgg 18

<210> SEQ ID NO 49
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 49

gtcggctcttc catttgc 17

<210> SEQ ID NO 50
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 50

cgaccactgt atcttgg 17

<210> SEQ ID NO 51
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 51

gagatgcaa acagtgc 17

<210> SEQ ID NO 52
<211> LENGTH: 16
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 52

catgtccatc gtgacg 16

<210> SEQ ID NO 53
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 53

caggagcatt tgatagc 17

<210> SEQ ID NO 54
<211> LENGTH: 16
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 54

ccttcagatg tgatcc 16

<210> SEQ ID NO 55
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 55

gtggtgacgt caactgc 17

<210> SEQ ID NO 56

-continued

<211> LENGTH: 18
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 56

gttcagcctt tcctctcg 18

<210> SEQ ID NO 57
<211> LENGTH: 18
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 57

gctaccttct ttcttagg 18

<210> SEQ ID NO 58
<211> LENGTH: 18
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 58

cgtaaatatg atctgtgc 18

<210> SEQ ID NO 59
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 59

ggaaagaagg tctgtgc 17

<210> SEQ ID NO 60
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 60

cagctatcag ctgacag 17

<210> SEQ ID NO 61
<211> LENGTH: 20
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 61

gctcagctat gacatattcc 20

<210> SEQ ID NO 62
<211> LENGTH: 17
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 62

gatcgtcttg attaccg 17

<210> SEQ ID NO 63
<211> LENGTH: 16
<212> TYPE: DNA
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 63

agctttatcg gtgacg 16

<210> SEQ ID NO 64

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<211> LENGTH: 16
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 64

 tgagcacgat tgcagg 16

 <210> SEQ ID NO 65
 <211> LENGTH: 17
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 65

 cattgCGGag acattgc 17

 <210> SEQ ID NO 66
 <211> LENGTH: 26
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 66

 tagacaattg gaagagaaaa gagata 26

 <210> SEQ ID NO 67
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 67

 ccgtcgctat tgtaaccagt 20

 <210> SEQ ID NO 68
 <211> LENGTH: 29
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 68

 ggaattccaa agctgcagcg gccggcgcg 29

 <210> SEQ ID NO 69
 <211> LENGTH: 32
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 69

 gaagatctcg tatacttggc ttctgcagct gc 32

 <210> SEQ ID NO 70
 <211> LENGTH: 31
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 70

 gaagatctgg tcaacaagct ggaaagcact c 31

 <210> SEQ ID NO 71
 <211> LENGTH: 33
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 71

 cccaagcttc gtgacgtaca gcaccgttcc ggc 33

 <210> SEQ ID NO 72

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<211> LENGTH: 50
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 72

 ccttaagggc cgaatattta tacggagctc cctgaaacaa caaaaacggc 50

<210> SEQ ID NO 73
 <211> LENGTH: 34
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 73

 ggtgttctct agagcggccg cggttgcggt cagc 34

<210> SEQ ID NO 74
 <211> LENGTH: 27
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 74

 gtccttcttg gtacctgaa gcagagc 27

<210> SEQ ID NO 75
 <211> LENGTH: 39
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 75

 gtataaatat tggccctta aggccagtac cattttccc 39

<210> SEQ ID NO 76
 <211> LENGTH: 13
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 76

 gggccggatc cgc 13

<210> SEQ ID NO 77
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 77

 attcccggcc taggcgccc 20

<210> SEQ ID NO 78
 <211> LENGTH: 19
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 78

 ggaaattatc gtgatcaac 19

<210> SEQ ID NO 79
 <211> LENGTH: 21
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

 <400> SEQUENCE: 79

 gcacgagcac tgataaatat g 21

<210> SEQ ID NO 80

-continued

<211> LENGTH: 21
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 80

catatttatac agtgctcgtg c 21

<210> SEQ ID NO 81
 <211> LENGTH: 17
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 81

tcgtagacct catatgc 17

<210> SEQ ID NO 82
 <211> LENGTH: 17
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 82

gtcgttaaac cgtgtgc 17

<210> SEQ ID NO 83
 <211> LENGTH: 39
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 83

ctagaggatac cccgggtacc gtgctctgcc ttttagtcc 39

<210> SEQ ID NO 84
 <211> LENGTH: 37
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 84

gtacatcgaa ttcgtgctca ttattaatct gttcagc 37

<210> SEQ ID NO 85
 <211> LENGTH: 20
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 85

aactattgcc gatgataagc 20

<210> SEQ ID NO 86
 <211> LENGTH: 1260
 <212> TYPE: DNA
 <213> ORGANISM: Bacillus subtilis
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(1260)

<400> SEQUENCE: 86

atg aaa aaa gtg atg tta gct acg gct ttg ttt tta gga ttg act cca 48
 Met Lys Lys Val Met Leu Ala Thr Ala Leu Phe Leu Gly Leu Thr Pro
 1 5 10 15

gct ggc gcg aac gca gct gat tta ggc cac cag acg ttg gga tcc aat 96
 Ala Gly Ala Asn Ala Ala Asp Leu Gly His Gln Thr Leu Gly Ser Asn
 20 25 30

gat ggc tgg ggc gcg tac tcg acc ggc acg aca ggc gga tca aaa gca 144
 Asp Gly Trp Gly Ala Tyr Ser Thr Gly Thr Thr Gly Gly Ser Lys Ala
 35 40 45

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| | |
|---|------|
| tcc tcc tca aat gtg tat acc gtc agc aac aga aac cag ctt gtc tcg Ser Ser Ser Asn Val Tyr Thr Val Ser Asn Arg Asn Gln Leu Val Ser 50 55 60 | 192 |
| gca tta ggg aag gaa acg aac aca acg cca aaa atc att tat atc aag Ala Leu Gly Lys Glu Thr Asn Thr Thr Pro Lys Ile Ile Tyr Ile Lys 65 70 75 80 | 240 |
| gga acg att gac atg aac gtg gat gac aat ctg aag ccg ctt ggc cta Gly Thr Ile Asp Met Asn Val Asp Asp Asn Leu Lys Pro Leu Gly Leu 85 90 95 | 288 |
| aat gac tat aaa gat ccg gag tat gat ttg gac aaa tat ttg aaa gcc Asn Asp Tyr Lys Asp Pro Glu Tyr Asp Leu Asp Lys Tyr Leu Lys Ala 100 105 110 | 336 |
| tat gat cct agc aca tgg ggc aaa aaa gag ccg tcg gga aca caa gaa Tyr Asp Pro Ser Thr Trp Gly Lys Lys Glu Pro Ser Gly Thr Gln Glu 115 120 125 | 384 |
| gaa gcg aga gca cgc tct cag aaa aac caa aaa gca cgg gtc atg gtg Glu Ala Arg Ala Arg Ser Gln Lys Asn Gln Lys Ala Arg Val Met Val 130 135 140 | 432 |
| gat atc cct gca aac acg acg atc gtc ggt tca ggg act aac gct aaa Asp Ile Pro Ala Asn Thr Thr Ile Val Gly Ser Gly Thr Asn Ala Lys 145 150 155 160 | 480 |
| gtc gtg gga gga aac ttc caa atc aag agt gat aac gtc att att cgc Val Val Gly Gly Asn Phe Gln Ile Lys Ser Asp Asn Val Ile Ile Arg 165 170 175 | 528 |
| aac att gaa ttc cag gat gcc tat gac tat ttt ccg caa tgg gat ccg Asn Ile Glu Phe Gln Asp Ala Tyr Asp Tyr Phe Pro Gln Trp Asp Pro 180 185 190 | 576 |
| act gac gga agc tca ggg aac tgg aac tca caa tac gac aac atc acg Thr Asp Gly Ser Ser Gly Asn Trp Asn Ser Gln Tyr Asp Asn Ile Thr 195 200 205 | 624 |
| ata aac ggc ggc aca cac atc tgg att gat cac tgt aca ttt aat gac Ile Asn Gly Gly Thr His Ile Trp Ile Asp His Cys Thr Phe Asn Asp 210 215 220 | 672 |
| ggt tcg cgt ccg gac agc aca tca ccg aaa tat tat gga aga aaa tat Gly Ser Arg Pro Asp Ser Thr Ser Pro Lys Tyr Tyr Gly Arg Lys Tyr 225 230 235 240 | 720 |
| cag cac cat gac ggc caa acg gat gct tcc aac ggt gct aac tat atc Gln His His Asp Gly Gln Thr Asp Ala Ser Asn Gly Ala Asn Tyr Ile 245 250 255 | 768 |
| acg atg tcc tac aac tat tat cac gat cat gat aaa agc tcc att ttc Thr Met Ser Tyr Asn Tyr Tyr His Asp His Asp Lys Ser Ser Ile Phe 260 265 270 | 816 |
| gga tca agt gac agc aaa acc tcc gat gac ggc aaa tta aaa att acg Gly Ser Ser Asp Ser Lys Thr Ser Asp Asp Gly Lys Leu Lys Ile Thr 275 280 285 | 864 |
| ctg cat cat aac cgc tat aaa aat att gtc cag cgc gcg ccg aga gtc Leu His His Asn Arg Tyr Lys Asn Ile Val Gln Arg Ala Pro Arg Val 290 295 300 | 912 |
| cgc ttc ggg caa gtg cac gta tac aac aac tat tat gaa gga agc aca Arg Phe Gly Gln Val His Val Tyr Asn Asn Tyr Tyr Glu Gly Ser Thr 305 310 315 320 | 960 |
| agc tct tca agt tat cct ttt agc tat gca tgg gga atc gga aag tca Ser Ser Ser Ser Tyr Pro Phe Ser Tyr Ala Trp Gly Ile Gly Lys Ser 325 330 335 | 1008 |
| tct aaa atc tat gcc caa aac aat gtc att gac gta ccg gga ctg tca Ser Lys Ile Tyr Ala Gln Asn Asn Val Ile Asp Val Pro Gly Leu Ser 340 345 350 | 1056 |
| gct gct aaa acg atc agc gta ttc agc ggg gga acg gct tta tat gac Ala Ala Lys Thr Ile Ser Val Phe Ser Gly Gly Thr Ala Leu Tyr Asp 355 360 365 | 1104 |

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tcc ggc acg ttg ctg aac ggc aca cag atc aac gca tgc gct gca aac    1152
Ser Gly Thr Leu Leu Asn Gly Thr Gln Ile Asn Ala Ser Ala Ala Asn
   370                               375                               380

ggg ctg agc tct tct gtc ggc tgg acg ccg tct ctg cat gga tgc att    1200
Gly Leu Ser Ser Ser Val Gly Trp Thr Pro Ser Leu His Gly Ser Ile
   385                               390                               395                               400

gat gct tct gct aat gtg aaa tca aat gtt ata aat caa gcg ggt gcg    1248
Asp Ala Ser Ala Asn Val Lys Ser Asn Val Ile Asn Gln Ala Gly Ala
                   405                               410                               415

ggt aaa tta aat    1260
Gly Lys Leu Asn
                   420

<210> SEQ ID NO 87
<211> LENGTH: 420
<212> TYPE: PRT
<213> ORGANISM: Bacillus subtilis

<400> SEQUENCE: 87

Met Lys Lys Val Met Leu Ala Thr Ala Leu Phe Leu Gly Leu Thr Pro
 1      5      10      15
Ala Gly Ala Asn Ala Ala Asp Leu Gly His Gln Thr Leu Gly Ser Asn
 20      25      30
Asp Gly Trp Gly Ala Tyr Ser Thr Gly Thr Thr Gly Gly Ser Lys Ala
 35      40      45
Ser Ser Ser Asn Val Tyr Thr Val Ser Asn Arg Asn Gln Leu Val Ser
 50      55      60
Ala Leu Gly Lys Glu Thr Asn Thr Thr Pro Lys Ile Ile Tyr Ile Lys
 65      70      75      80
Gly Thr Ile Asp Met Asn Val Asp Asp Asn Leu Lys Pro Leu Gly Leu
 85      90      95
Asn Asp Tyr Lys Asp Pro Glu Tyr Asp Leu Asp Lys Tyr Leu Lys Ala
100     105     110
Tyr Asp Pro Ser Thr Trp Gly Lys Lys Glu Pro Ser Gly Thr Gln Glu
115     120     125
Glu Ala Arg Ala Arg Ser Gln Lys Asn Gln Lys Ala Arg Val Met Val
130     135     140
Asp Ile Pro Ala Asn Thr Thr Ile Val Gly Ser Gly Thr Asn Ala Lys
145     150     155     160
Val Val Gly Gly Asn Phe Gln Ile Lys Ser Asp Asn Val Ile Ile Arg
165     170     175
Asn Ile Glu Phe Gln Asp Ala Tyr Asp Tyr Phe Pro Gln Trp Asp Pro
180     185     190
Thr Asp Gly Ser Ser Gly Asn Trp Asn Ser Gln Tyr Asp Asn Ile Thr
195     200     205
Ile Asn Gly Gly Thr His Ile Trp Ile Asp His Cys Thr Phe Asn Asp
210     215     220
Gly Ser Arg Pro Asp Ser Thr Ser Pro Lys Tyr Tyr Gly Arg Lys Tyr
225     230     235     240
Gln His His Asp Gly Gln Thr Asp Ala Ser Asn Gly Ala Asn Tyr Ile
245     250     255
Thr Met Ser Tyr Asn Tyr Tyr His Asp His Asp Lys Ser Ser Ile Phe
260     265     270
Gly Ser Ser Asp Ser Lys Thr Ser Asp Asp Gly Lys Leu Lys Ile Thr
275     280     285
Leu His His Asn Arg Tyr Lys Asn Ile Val Gln Arg Ala Pro Arg Val

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| 290 | 295 | 300 | |
|---|-----|-----|-----|
| Arg Phe Gly Gln Val His Val Tyr Asn Asn Tyr Tyr Glu Gly Ser Thr | | | |
| 305 | 310 | 315 | 320 |
| Ser Ser Ser Ser Tyr Pro Phe Ser Tyr Ala Trp Gly Ile Gly Lys Ser | | | |
| | 325 | 330 | 335 |
| Ser Lys Ile Tyr Ala Gln Asn Asn Val Ile Asp Val Pro Gly Leu Ser | | | |
| | 340 | 345 | 350 |
| Ala Ala Lys Thr Ile Ser Val Phe Ser Gly Gly Thr Ala Leu Tyr Asp | | | |
| | 355 | 360 | 365 |
| Ser Gly Thr Leu Leu Asn Gly Thr Gln Ile Asn Ala Ser Ala Ala Asn | | | |
| | 370 | 375 | 380 |
| Gly Leu Ser Ser Ser Val Gly Trp Thr Pro Ser Leu His Gly Ser Ile | | | |
| 385 | 390 | 395 | 400 |
| Asp Ala Ser Ala Asn Val Lys Ser Asn Val Ile Asn Gln Ala Gly Ala | | | |
| | 405 | 410 | 415 |
| Gly Lys Leu Asn | | | |
| | 420 | | |
| | | | |
| <210> SEQ ID NO 88 | | | |
| <211> LENGTH: 26 | | | |
| <212> TYPE: DNA | | | |
| <213> ORGANISM: Bacillus subtilis | | | |
| | | | |
| <400> SEQUENCE: 88 | | | |
| actagtaatg atggctgggg cgcgta | | | 26 |
| | | | |
| <210> SEQ ID NO 89 | | | |
| <211> LENGTH: 26 | | | |
| <212> TYPE: DNA | | | |
| <213> ORGANISM: Bacillus subtilis | | | |
| | | | |
| <400> SEQUENCE: 89 | | | |
| gtcgacatgt tgtcgtattg tgagtt | | | 26 |
| | | | |
| <210> SEQ ID NO 90 | | | |
| <211> LENGTH: 52 | | | |
| <212> TYPE: DNA | | | |
| <213> ORGANISM: Bacillus subtilis | | | |
| | | | |
| <400> SEQUENCE: 90 | | | |
| gagctctaca acgcttatgg atccgcgggcc gggcgggcac acacatctgg at | | | 52 |
| | | | |
| <210> SEQ ID NO 91 | | | |
| <211> LENGTH: 26 | | | |
| <212> TYPE: DNA | | | |
| <213> ORGANISM: Bacillus subtilis | | | |
| | | | |
| <400> SEQUENCE: 91 | | | |
| gacgtcagcc cgtttgcagc cgatgc | | | 26 |
| | | | |
| <210> SEQ ID NO 92 | | | |
| <211> LENGTH: 1257 | | | |
| <212> TYPE: DNA | | | |
| <213> ORGANISM: Streptococcus pyogenes | | | |
| <220> FEATURE: | | | |
| <221> NAME/KEY: CDS | | | |
| <222> LOCATION: (1)..(1257) | | | |
| | | | |
| <400> SEQUENCE: 92 | | | |
| gtg cct att ttt aaa aaa act tta att gtt tta tcc ttt att ttt ttg | | | 48 |
| Val Pro Ile Phe Lys Lys Thr Leu Ile Val Leu Ser Phe Ile Phe Leu | | | |
| 1 | 5 | 10 | 15 |

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| | |
|---|------|
| ata tct atc ttg att tat cta aat atg tat cta ttt gga aca tca act | 96 |
| Ile Ser Ile Leu Ile Tyr Leu Asn Met Tyr Leu Phe Gly Thr Ser Thr | |
| 20 25 30 | |
| gta gga att tat gga gta ata tta ata acc tat cta gtt att aaa ctt | 144 |
| Val Gly Ile Tyr Gly Val Ile Leu Ile Thr Tyr Leu Val Ile Lys Leu | |
| 35 40 45 | |
| gga tta tct ttc ctt tat gag cca ttt aaa gga aag cca cat gac tat | 192 |
| Gly Leu Ser Phe Leu Tyr Glu Pro Phe Lys Gly Lys Pro His Asp Tyr | |
| 50 55 60 | |
| aaa gtt gct gct gta att cct tct tat aat gaa gat gcc gag tca tta | 240 |
| Lys Val Ala Ala Val Ile Pro Ser Tyr Asn Glu Asp Ala Glu Ser Leu | |
| 65 70 75 80 | |
| tta gaa act ctt aaa agt gtg tta gca cag acc tat ccg tta tca gaa | 288 |
| Leu Glu Thr Leu Lys Ser Val Leu Ala Gln Thr Tyr Pro Leu Ser Glu | |
| 85 90 95 | |
| att tat att gtt gat gat ggg agt tca aac aca gat gca ata caa tta | 336 |
| Ile Tyr Ile Val Asp Asp Gly Ser Ser Asn Thr Asp Ala Ile Gln Leu | |
| 100 105 110 | |
| att gaa gag tat gta aat aga gaa gtg gat att tgt cga aac gtt atc | 384 |
| Ile Glu Glu Tyr Val Asn Arg Glu Val Asp Ile Cys Arg Asn Val Ile | |
| 115 120 125 | |
| gtt cac cgt tcc ctt gtc aat aaa gga aaa cgc cat gct caa gcg tgg | 432 |
| Val His Arg Ser Leu Val Asn Lys Gly Lys Arg His Ala Gln Ala Trp | |
| 130 135 140 | |
| gca ttt gaa aga tct gac gct gac gtt ttt tta acc gta gat tca gat | 480 |
| Ala Phe Glu Arg Ser Asp Ala Asp Val Phe Leu Thr Val Asp Ser Asp | |
| 145 150 155 160 | |
| act tat atc tat cca aat gcc tta gaa gaa ctc cta aaa agc ttc aat | 528 |
| Thr Tyr Ile Tyr Pro Asn Ala Leu Glu Glu Leu Leu Lys Ser Phe Asn | |
| 165 170 175 | |
| gat gag aca gtt tat gct gca aca gga cat ttg aat gct aga aac aga | 576 |
| Asp Glu Thr Val Tyr Ala Ala Thr Gly His Leu Asn Ala Arg Asn Arg | |
| 180 185 190 | |
| caa act aat cta tta acg cga ctt aca gat atc cgt tac gat aat gcc | 624 |
| Gln Thr Asn Leu Leu Thr Arg Leu Thr Asp Ile Arg Tyr Asp Asn Ala | |
| 195 200 205 | |
| ttt ggg gtg gag cgt gct gct caa tca tta aca ggt aat att tta gtt | 672 |
| Phe Gly Val Glu Arg Ala Ala Gln Ser Leu Thr Gly Asn Ile Leu Val | |
| 210 215 220 | |
| tgc tca gga cca ttg agt att tat cga cgt gaa gtg att att cct aac | 720 |
| Cys Ser Gly Pro Leu Ser Ile Tyr Arg Arg Glu Val Ile Ile Pro Asn | |
| 225 230 235 240 | |
| tta gag cgc tat aaa aat caa aca ttc cta ggt tta cct gtt agc att | 768 |
| Leu Glu Arg Tyr Lys Asn Gln Thr Phe Leu Gly Leu Pro Val Ser Ile | |
| 245 250 255 | |
| ggg gat gat cga tgt tta aca aat tat gct att gat tta gga cgc act | 816 |
| Gly Asp Asp Arg Cys Leu Thr Asn Tyr Ala Ile Asp Leu Gly Arg Thr | |
| 260 265 270 | |
| gtc tac caa tca aca gct aga tgt gat act gat gta cct ttc caa tta | 864 |
| Val Tyr Gln Ser Thr Ala Arg Cys Asp Thr Asp Val Pro Phe Gln Leu | |
| 275 280 285 | |
| aaa agt tat tta aag caa caa aat cga tgg aat aaa tct ttt ttt aaa | 912 |
| Lys Ser Tyr Leu Lys Gln Gln Asn Arg Trp Asn Lys Ser Phe Phe Lys | |
| 290 295 300 | |
| gaa tct att att tct gtt aaa aaa att ctt tct aat ccc atc gtt gcc | 960 |
| Glu Ser Ile Ile Ser Val Lys Lys Ile Leu Ser Asn Pro Ile Val Ala | |
| 305 310 315 320 | |
| tta tgg act att ttc gaa gtc gtt atg ttt atg atg ttg att gtc gca | 1008 |
| Leu Trp Thr Ile Phe Glu Val Val Met Phe Met Met Leu Ile Val Ala | |
| 325 330 335 | |

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att ggg aat ctt ttg ttt aat caa gct att caa tta gac ctt att aaa 1056
 Ile Gly Asn Leu Leu Phe Asn Gln Ala Ile Gln Leu Asp Leu Ile Lys
 340 345 350

ctt ttt gcc ttt tta tcc atc atc ttt atc gtt gct tta tgt cgt aat 1104
 Leu Phe Ala Phe Leu Ser Ile Ile Phe Ile Val Ala Leu Cys Arg Asn
 355 360 365

gtt cat tat atg atc aaa cat cct gct agt ttt ttg tta tct cct ctg 1152
 Val His Tyr Met Ile Lys His Pro Ala Ser Phe Leu Leu Ser Pro Leu
 370 375 380

tat gga ata tta cac ttg ttt gtc tta cag ccc cta aaa ctt tat tct 1200
 Tyr Gly Ile Leu His Leu Phe Val Leu Gln Pro Leu Lys Leu Tyr Ser
 385 390 395 400

tta tgc acc att aaa aat acg gaa tgg gga aca cgt aaa aag gtc act 1248
 Leu Cys Thr Ile Lys Asn Thr Glu Trp Gly Thr Arg Lys Lys Val Thr
 405 410 415

att ttt aaa 1257
 Ile Phe Lys

<210> SEQ ID NO 93
 <211> LENGTH: 419
 <212> TYPE: PRT
 <213> ORGANISM: Streptococcus pyogenes

<400> SEQUENCE: 93

Val Pro Ile Phe Lys Lys Thr Leu Ile Val Leu Ser Phe Ile Phe Leu
 1 5 10 15

Ile Ser Ile Leu Ile Tyr Leu Asn Met Tyr Leu Phe Gly Thr Ser Thr
 20 25 30

Val Gly Ile Tyr Gly Val Ile Leu Ile Thr Tyr Leu Val Ile Lys Leu
 35 40 45

Gly Leu Ser Phe Leu Tyr Glu Pro Phe Lys Gly Lys Pro His Asp Tyr
 50 55 60

Lys Val Ala Ala Val Ile Pro Ser Tyr Asn Glu Asp Ala Glu Ser Leu
 65 70 75 80

Leu Glu Thr Leu Lys Ser Val Leu Ala Gln Thr Tyr Pro Leu Ser Glu
 85 90 95

Ile Tyr Ile Val Asp Asp Gly Ser Ser Asn Thr Asp Ala Ile Gln Leu
 100 105 110

Ile Glu Glu Tyr Val Asn Arg Glu Val Asp Ile Cys Arg Asn Val Ile
 115 120 125

Val His Arg Ser Leu Val Asn Lys Gly Lys Arg His Ala Gln Ala Trp
 130 135 140

Ala Phe Glu Arg Ser Asp Ala Asp Val Phe Leu Thr Val Asp Ser Asp
 145 150 155 160

Thr Tyr Ile Tyr Pro Asn Ala Leu Glu Glu Leu Leu Lys Ser Phe Asn
 165 170 175

Asp Glu Thr Val Tyr Ala Ala Thr Gly His Leu Asn Ala Arg Asn Arg
 180 185 190

Gln Thr Asn Leu Leu Thr Arg Leu Thr Asp Ile Arg Tyr Asp Asn Ala
 195 200 205

Phe Gly Val Glu Arg Ala Ala Gln Ser Leu Thr Gly Asn Ile Leu Val
 210 215 220

Cys Ser Gly Pro Leu Ser Ile Tyr Arg Arg Glu Val Ile Ile Pro Asn
 225 230 235 240

Leu Glu Arg Tyr Lys Asn Gln Thr Phe Leu Gly Leu Pro Val Ser Ile
 245 250 255

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Gly Asp Asp Arg Cys Leu Thr Asn Tyr Ala Ile Asp Leu Gly Arg Thr
 260 265 270
 Val Tyr Gln Ser Thr Ala Arg Cys Asp Thr Asp Val Pro Phe Gln Leu
 275 280 285
 Lys Ser Tyr Leu Lys Gln Gln Asn Arg Trp Asn Lys Ser Phe Phe Lys
 290 295 300
 Glu Ser Ile Ile Ser Val Lys Lys Ile Leu Ser Asn Pro Ile Val Ala
 305 310 315 320
 Leu Trp Thr Ile Phe Glu Val Val Met Phe Met Met Leu Ile Val Ala
 325 330 335
 Ile Gly Asn Leu Leu Phe Asn Gln Ala Ile Gln Leu Asp Leu Ile Lys
 340 345 350
 Leu Phe Ala Phe Leu Ser Ile Ile Phe Ile Val Ala Leu Cys Arg Asn
 355 360 365
 Val His Tyr Met Ile Lys His Pro Ala Ser Phe Leu Leu Ser Pro Leu
 370 375 380
 Tyr Gly Ile Leu His Leu Phe Val Leu Gln Pro Leu Lys Leu Tyr Ser
 385 390 395 400
 Leu Cys Thr Ile Lys Asn Thr Glu Trp Gly Thr Arg Lys Lys Val Thr
 405 410 415
 Ile Phe Lys

<210> SEQ ID NO 94
 <211> LENGTH: 2916
 <212> TYPE: DNA
 <213> ORGANISM: Pasteurella multocida
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(2916)

<400> SEQUENCE: 94

atg aat aca tta tca caa gca ata aaa gca tat aac agc aat gac tat 48
 Met Asn Thr Leu Ser Gln Ala Ile Lys Ala Tyr Asn Ser Asn Asp Tyr
 1 5 10 15
 caa tta gca ctc aaa tta ttt gaa aag tcg gcg gaa atc tat gga cgg 96
 Gln Leu Ala Leu Lys Leu Phe Glu Lys Ser Ala Glu Ile Tyr Gly Arg
 20 25 30
 aaa att gtt gaa ttt caa att acc aaa tgc caa gaa aaa ctc tca gca 144
 Lys Ile Val Glu Phe Gln Ile Thr Lys Cys Gln Glu Lys Leu Ser Ala
 35 40 45
 cat cct tct gtt aat tca gca cat ctt tct gta aat aaa gaa gaa aaa 192
 His Pro Ser Val Asn Ser Ala His Leu Ser Val Asn Lys Glu Glu Lys
 50 55 60
 gtc aat gtt tgc gat agt ccg tta gat att gca aca caa ctg tta ctt 240
 Val Asn Val Cys Asp Ser Pro Leu Asp Ile Ala Thr Gln Leu Leu Leu
 65 70 75 80
 tcc aac gta aaa aaa tta gta ctt tct gac tcg gaa aaa aac acg tta 288
 Ser Asn Val Lys Lys Leu Val Leu Ser Asp Ser Glu Lys Asn Thr Leu
 85 90 95
 aaa aat aaa tgg aaa ttg ctc act gag aag aaa tct gaa aat gcg gag 336
 Lys Asn Lys Trp Lys Leu Leu Thr Glu Lys Lys Ser Glu Asn Ala Glu
 100 105 110
 gta aga gcg gtc gcc ctt gta cca aaa gat ttt ccc aaa gat ctg gtt 384
 Val Arg Ala Val Ala Leu Val Pro Lys Asp Phe Pro Lys Asp Leu Val
 115 120 125
 tta gcg cct tta cct gat cat gtt aat gat ttt aca tgg tac aaa aag 432
 Leu Ala Pro Leu Pro Asp His Val Asn Asp Phe Thr Trp Tyr Lys Lys
 130 135 140
 cga aag aaa aga ctt ggc ata aaa cct gaa cat caa cat gtt ggt ctt 480

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| | | | | | | | | | | | | | | | | |
|------------|-----|-----|-----|-----|------------|-----|-----|-----|-----|------------|-----|-----|-----|-----|------------|------|
| Arg 145 | Lys | Lys | Arg | Leu | Gly 150 | Ile | Lys | Pro | Glu | His 155 | Gln | His | Val | Gly | Leu 160 | |
| tct | att | atc | gtt | aca | aca | ttc | aat | cga | cca | gca | att | tta | tcg | att | aca | 528 |
| Ser | Ile | Ile | Val | Thr | Thr | Phe | Asn | Arg | Pro | Ala | Ile | Leu | Ser | Ile | Thr | |
| | | | 165 | | | | | 170 | | | | | 175 | | | |
| tta | gcc | tgt | tta | gta | aac | caa | aaa | aca | cat | tac | ccg | ttt | gaa | gtt | atc | 576 |
| Leu | Ala | Cys | Leu | Val | Asn | Gln | Lys | Thr | His | Tyr | Pro | Phe | Glu | Val | Ile | |
| | | | 180 | | | | | 185 | | | | | 190 | | | |
| gtg | aca | gat | gat | ggt | agt | cag | gaa | gat | cta | tca | ccg | atc | att | cgc | caa | 624 |
| Val | Thr | Asp | Asp | Gly | Ser | Gln | Glu | Asp | Leu | Ser | Pro | Ile | Ile | Arg | Gln | |
| | | 195 | | | | | 200 | | | | | 205 | | | | |
| tat | gaa | aat | aaa | ttg | gat | att | cgc | tac | gtc | aga | caa | aaa | gat | aac | ggt | 672 |
| Tyr | Glu | Asn | Lys | Leu | Asp | Ile | Arg | Tyr | Val | Arg | Gln | Lys | Asp | Asn | Gly | |
| | 210 | | | | | 215 | | | | 220 | | | | | | |
| ttt | caa | gcc | agt | gcc | gct | cgg | aat | atg | gga | tta | cgc | tta | gca | aaa | tat | 720 |
| Phe | Gln | Ala | Ser | Ala | Ala | Arg | Asn | Met | Gly | Leu | Arg | Leu | Ala | Lys | Tyr | |
| 225 | | | | 230 | | | | | 235 | | | | | | 240 | |
| gac | ttt | att | ggc | tta | ctc | gac | tgt | gat | atg | gcg | cca | aat | cca | tta | tgg | 768 |
| Asp | Phe | Ile | Gly | Leu | Leu | Asp | Cys | Asp | Met | Ala | Pro | Asn | Pro | Leu | Trp | |
| | | | 245 | | | | | 250 | | | | | | 255 | | |
| gtt | cat | tct | tat | gtt | gca | gag | cta | tta | gaa | gat | gat | gat | tta | aca | atc | 816 |
| Val | His | Ser | Tyr | Val | Ala | Glu | Leu | Leu | Glu | Asp | Asp | Asp | Leu | Thr | Ile | |
| | | | 260 | | | | | 265 | | | | | 270 | | | |
| att | ggt | cca | aga | aaa | tac | atc | gat | aca | caa | cat | att | gac | cca | aaa | gac | 864 |
| Ile | Gly | Pro | Arg | Lys | Tyr | Ile | Asp | Thr | Gln | His | Ile | Asp | Pro | Lys | Asp | |
| | | 275 | | | | | 280 | | | | | 285 | | | | |
| ttc | tta | aat | aac | gcg | agt | ttg | ctt | gaa | tca | tta | cca | gaa | gtg | aaa | acc | 912 |
| Phe | Leu | Asn | Asn | Ala | Ser | Leu | Leu | Glu | Ser | Leu | Pro | Glu | Val | Lys | Thr | |
| | 290 | | | | | 295 | | | | | 300 | | | | | |
| aat | aat | agt | gtt | gcc | gca | aaa | ggg | gaa | gga | aca | gtt | tct | ctg | gat | tgg | 960 |
| Asn | Asn | Ser | Val | Ala | Ala | Lys | Gly | Glu | Gly | Thr | Val | Ser | Leu | Asp | Trp | |
| 305 | | | | 310 | | | | | 315 | | | | | 320 | | |
| cgc | tta | gaa | caa | ttc | gaa | aaa | aca | gaa | aat | ctc | cgc | tta | tcc | gat | tcg | 1008 |
| Arg | Leu | Glu | Gln | Phe | Glu | Lys | Thr | Glu | Asn | Leu | Arg | Leu | Ser | Asp | Ser | |
| | | | 325 | | | | | 330 | | | | | | 335 | | |
| cct | ttc | cgt | ttt | ttt | gcg | gcg | ggt | aat | gtt | gct | ttc | gct | aaa | aaa | tgg | 1056 |
| Pro | Phe | Arg | Phe | Phe | Ala | Ala | Gly | Asn | Val | Ala | Phe | Ala | Lys | Lys | Trp | |
| | | | 340 | | | | 345 | | | | | | 350 | | | |
| cta | aat | aaa | tcc | ggt | ttc | ttt | gat | gag | gaa | ttt | aat | cac | tgg | ggt | gga | 1104 |
| Leu | Asn | Lys | Ser | Gly | Phe | Phe | Asp | Glu | Glu | Phe | Asn | His | Trp | Gly | Gly | |
| | | 355 | | | | | 360 | | | | | 365 | | | | |
| gaa | gat | gtg | gaa | ttt | gga | tat | cgc | tta | ttc | cgt | tac | ggt | agt | ttc | ttt | 1152 |
| Glu | Asp | Val | Glu | Phe | Gly | Tyr | Arg | Leu | Phe | Arg | Tyr | Gly | Ser | Phe | Phe | |
| | 370 | | | | | 375 | | | | 380 | | | | | | |
| aaa | act | att | gat | ggc | att | atg | gcc | tac | cat | caa | gag | cca | cca | ggt | aaa | 1200 |
| Lys | Thr | Ile | Asp | Gly | Ile | Met | Ala | Tyr | His | Gln | Glu | Pro | Pro | Gly | Lys | |
| 385 | | | | 390 | | | | | | 395 | | | | 400 | | |
| gaa | aat | gaa | acc | gat | cgt | gaa | gcg | gga | aaa | aat | att | acg | ctc | gat | att | 1248 |
| Glu | Asn | Glu | Thr | Asp | Arg | Glu | Ala | Gly | Lys | Asn | Ile | Thr | Leu | Asp | Ile | |
| | | | 405 | | | | | 410 | | | | | 415 | | | |
| atg | aga | gaa | aag | gtc | cct | tat | atc | tat | aga | aaa | ctt | tta | cca | ata | gaa | 1296 |
| Met | Arg | Glu | Lys | Val | Pro | Tyr | Ile | Tyr | Arg | Lys | Leu | Leu | Pro | Ile | Glu | |
| | | | 420 | | | | 425 | | | | | | 430 | | | |
| gat | tcg | cat | atc | aat | aga | gta | cct | tta | gtt | tca | att | tat | atc | cca | gct | 1344 |
| Asp | Ser | His | Ile | Asn | Arg | Val | Pro | Leu | Val | Ser | Ile | Tyr | Ile | Pro | Ala | |
| | | 435 | | | | 440 | | | | | | 445 | | | | |
| tat | aac | tgt | gca | aac | tat | att | caa | cgt | tgc | gta | gat | agt | gca | ctg | aat | 1392 |
| Tyr | Asn | Cys | Ala | Asn | Tyr | Ile | Gln | Arg | Cys | Val | Asp | Ser | Ala | Leu | Asn | |
| | 450 | | | | | 455 | | | | 460 | | | | | | |
| cag | act | gtt | gtt | gat | ctc | gag | ggt | tgt | att | tgt | aac | gat | ggt | tca | aca | 1440 |

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| | |
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| Gln Thr Val Val Asp Leu Glu Val Cys Ile Cys Asn Asp Gly Ser Thr | |
| 465 | 470 475 480 |
| gat aat acc tta gaa gtg atc aat aag ctt tat ggt aat aat cct agg | 1488 |
| Asp Asn Thr Leu Glu Val Ile Asn Lys Leu Tyr Gly Asn Asn Pro Arg | |
| | 485 490 495 |
| gta cgc atc atg tct aaa cca aat ggc gga ata gcc tca gca tca aat | 1536 |
| Val Arg Ile Met Ser Lys Pro Asn Gly Gly Ile Ala Ser Ala Ser Asn | |
| | 500 505 510 |
| gca gcc gtt tct ttt gct aaa ggt tat tac att ggg cag tta gat tca | 1584 |
| Ala Ala Val Ser Phe Ala Lys Gly Tyr Tyr Ile Gly Gln Leu Asp Ser | |
| | 515 520 525 |
| gat gat tat ctt gag cct gat gca gtt gaa ctg tgt tta aaa gaa ttt | 1632 |
| Asp Asp Tyr Leu Glu Pro Asp Ala Val Glu Leu Cys Leu Lys Glu Phe | |
| | 530 535 540 |
| tta aaa gat aaa acg cta gct tgt gtt tat acc act aat aga aac gtc | 1680 |
| Leu Lys Asp Lys Thr Leu Ala Cys Val Tyr Thr Thr Asn Arg Asn Val | |
| | 545 550 555 560 |
| aat ccg gat ggt agc tta atc gct aat ggt tac aat tgg cca gaa ttt | 1728 |
| Asn Pro Asp Gly Ser Leu Ile Ala Asn Gly Tyr Asn Trp Pro Glu Phe | |
| | 565 570 575 |
| tca cga gaa aaa ctc aca acg gct atg att gct cac cac ttt aga atg | 1776 |
| Ser Arg Glu Lys Leu Thr Thr Ala Met Ile Ala His His Phe Arg Met | |
| | 580 585 590 |
| ttc acg att aga gct tgg cat tta act gat gga ttc aat gaa aaa att | 1824 |
| Phe Thr Ile Arg Ala Trp His Leu Thr Asp Gly Phe Asn Glu Lys Ile | |
| | 595 600 605 |
| gaa aat gcc gta gac tat gac atg ttc ctc aaa ctc agt gaa gtt gga | 1872 |
| Glu Asn Ala Val Asp Tyr Asp Met Phe Leu Lys Leu Ser Glu Val Gly | |
| | 610 615 620 |
| aaa ttt aaa cat ctt aat aaa atc tgc tat aac cgt gta tta cat ggt | 1920 |
| Lys Phe Lys His Leu Asn Lys Ile Cys Tyr Asn Arg Val Leu His Gly | |
| | 625 630 635 640 |
| gat aac aca tca att aag aaa ctt ggc att caa aag aaa aac cat ttt | 1968 |
| Asp Asn Thr Ser Ile Lys Lys Leu Gly Ile Gln Lys Lys Asn His Phe | |
| | 645 650 655 |
| gtt gta gtc aat cag tca tta aat aga caa ggc ata act tat tat aat | 2016 |
| Val Val Val Asn Gln Ser Leu Asn Arg Gln Gly Ile Thr Tyr Tyr Asn | |
| | 660 665 670 |
| tat gac gaa ttt gat gat tta gat gaa agt aga aag tat att ttc aat | 2064 |
| Tyr Asp Glu Phe Asp Asp Leu Asp Glu Ser Arg Lys Tyr Ile Phe Asn | |
| | 675 680 685 |
| aaa acc gct gaa tat caa gaa gag att gat atc tta aaa gat att aaa | 2112 |
| Lys Thr Ala Glu Tyr Gln Glu Glu Ile Asp Ile Leu Lys Asp Ile Lys | |
| | 690 695 700 |
| atc atc cag aat aaa gat gcc aaa atc gca gtc agt att ttt tat ccc | 2160 |
| Ile Ile Gln Asn Lys Asp Ala Lys Ile Ala Val Ser Ile Phe Tyr Pro | |
| | 705 710 715 720 |
| aat aca tta aac ggc tta gtg aaa aaa cta aac aat att att gaa tat | 2208 |
| Asn Thr Leu Asn Gly Leu Val Lys Lys Leu Asn Asn Ile Ile Glu Tyr | |
| | 725 730 735 |
| aat aaa aat ata ttc gtt att gtt cta cat gtt gat aag aat cat ctt | 2256 |
| Asn Lys Asn Ile Phe Val Ile Val Leu His Val Asp Lys Asn His Leu | |
| | 740 745 750 |
| aca cca gat atc aaa aaa gaa ata cta gcc ttc tat cat aaa cat caa | 2304 |
| Thr Pro Asp Ile Lys Lys Glu Ile Leu Ala Phe Tyr His Lys His Gln | |
| | 755 760 765 |
| gtg aat att tta cta aat aat gat atc tca tat tac acg agt aat aga | 2352 |
| Val Asn Ile Leu Leu Asn Asn Asp Ile Ser Tyr Tyr Thr Ser Asn Arg | |
| | 770 775 780 |
| tta ata aaa act gag gcg cat tta agt aat att aat aaa tta agt cag | 2400 |

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| | |
|---|------|
| Leu Ile Lys Thr Glu Ala His Leu Ser Asn Ile Asn Lys Leu Ser Gln 785 790 795 800 | |
| tta aat cta aat tgt gaa tac atc att ttt gat aat cat gac agc cta Leu Asn Leu Asn Cys Glu Tyr Ile Ile Phe Asp Asn His Asp Ser Leu 805 810 815 | 2448 |
| ttc gtt aaa aat gac agc tat gct tat atg aaa aaa tat gat gtc ggc Phe Val Lys Asn Asp Ser Tyr Ala Tyr Met Lys Lys Tyr Asp Val Gly 820 825 830 | 2496 |
| atg aat ttc tca gca tta aca cat gat tgg atc gag aaa atc aat gcg Met Asn Phe Ser Ala Leu Thr His Asp Trp Ile Glu Lys Ile Asn Ala 835 840 845 | 2544 |
| cat cca cca ttt aaa aag ctc att aaa act tat ttt aat gac aat gac His Pro Pro Phe Lys Lys Leu Ile Lys Thr Tyr Phe Asn Asp Asn Asp 850 855 860 | 2592 |
| tta aaa agt atg aat gtg aaa ggg gca tca caa ggt atg ttt atg acg Leu Lys Ser Met Asn Val Lys Gly Ala Ser Gln Gly Met Phe Met Thr 865 870 875 880 | 2640 |
| tat gcg cta gcg cat gag ctt ctg acg att att aaa gaa gtc atc aca Tyr Ala Leu Ala His Glu Leu Leu Thr Ile Ile Lys Glu Val Ile Thr 885 890 895 | 2688 |
| tct tgc cag tca att gat agt gtg cca gaa tat aac act gag gat att Ser Cys Gln Ser Ile Asp Ser Val Pro Glu Tyr Asn Thr Glu Asp Ile 900 905 910 | 2736 |
| tgg ttc caa ttt gca ctt tta atc tta gaa aag aaa acc ggc cat gta Trp Phe Gln Phe Ala Leu Leu Ile Leu Glu Lys Lys Thr Gly His Val 915 920 925 | 2784 |
| ttt aat aaa aca tcg acc ctg act tat atg cct tgg gaa cga aaa tta Phe Asn Lys Thr Ser Thr Leu Thr Tyr Met Pro Trp Glu Arg Lys Leu 930 935 940 | 2832 |
| caa tgg aca aat gaa caa att gaa agt gca aaa aga gga gaa aat ata Gln Trp Thr Asn Glu Gln Ile Glu Ser Ala Lys Arg Gly Glu Asn Ile 945 950 955 960 | 2880 |
| cct gtt aac aag ttc att att aat agt ata act cta Pro Val Asn Lys Phe Ile Ile Asn Ser Ile Thr Leu 965 970 | 2916 |

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<212> TYPE: PRT

<213> ORGANISM: Pasteurella multocida

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| Lys Ile Val Glu Phe Gln Ile Thr Lys Cys Gln Glu Lys Leu Ser Ala 35 40 45 |
| His Pro Ser Val Asn Ser Ala His Leu Ser Val Asn Lys Glu Glu Lys 50 55 60 |
| Val Asn Val Cys Asp Ser Pro Leu Asp Ile Ala Thr Gln Leu Leu Leu 65 70 75 80 |
| Ser Asn Val Lys Lys Leu Val Leu Ser Asp Ser Glu Lys Asn Thr Leu 85 90 95 |
| Lys Asn Lys Trp Lys Leu Leu Thr Glu Lys Lys Ser Glu Asn Ala Glu 100 105 110 |
| Val Arg Ala Val Ala Leu Val Pro Lys Asp Phe Pro Lys Asp Leu Val 115 120 125 |
| Leu Ala Pro Leu Pro Asp His Val Asn Asp Phe Thr Trp Tyr Lys Lys |

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| 130 | | | 135 | | | 140 | | | | | | | | | | |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Arg 145 | Lys | Lys | Arg | Leu | Gly | Ile | Lys | Pro | Glu | His | Gln | His | Val | Gly | Leu | 160 |
| Ser | Ile | Ile | Val | Thr | Thr | Phe | Asn | Arg | Pro | Ala | Ile | Leu | Ser | Ile | Thr | 175 |
| Leu | Ala | Cys | Leu | Val | Asn | Gln | Lys | Thr | His | Tyr | Pro | Phe | Glu | Val | Ile | 190 |
| Val | Thr | Asp | Asp | Gly | Ser | Gln | Glu | Asp | Leu | Ser | Pro | Ile | Ile | Arg | Gln | 205 |
| Tyr | Glu | Asn | Lys | Leu | Asp | Ile | Arg | Tyr | Val | Arg | Gln | Lys | Asp | Asn | Gly | 220 |
| Phe | Gln | Ala | Ser | Ala | Ala | Arg | Asn | Met | Gly | Leu | Arg | Leu | Ala | Lys | Tyr | 240 |
| Asp | Phe | Ile | Gly | Leu | Leu | Asp | Cys | Asp | Met | Ala | Pro | Asn | Pro | Leu | Trp | 255 |
| Val | His | Ser | Tyr | Val | Ala | Glu | Leu | Leu | Glu | Asp | Asp | Asp | Leu | Thr | Ile | 270 |
| Ile | Gly | Pro | Arg | Lys | Tyr | Ile | Asp | Thr | Gln | His | Ile | Asp | Pro | Lys | Asp | 285 |
| Phe | Leu | Asn | Asn | Ala | Ser | Leu | Leu | Glu | Ser | Leu | Pro | Glu | Val | Lys | Thr | 300 |
| Asn | Asn | Ser | Val | Ala | Ala | Lys | Gly | Glu | Gly | Thr | Val | Ser | Leu | Asp | Trp | 320 |
| Arg | Leu | Glu | Gln | Phe | Glu | Lys | Thr | Glu | Asn | Leu | Arg | Leu | Ser | Asp | Ser | 335 |
| Pro | Phe | Arg | Phe | Phe | Ala | Ala | Gly | Asn | Val | Ala | Phe | Ala | Lys | Lys | Trp | 350 |
| Leu | Asn | Lys | Ser | Gly | Phe | Phe | Asp | Glu | Glu | Phe | Asn | His | Trp | Gly | Gly | 365 |
| Glu | Asp | Val | Glu | Phe | Gly | Tyr | Arg | Leu | Phe | Arg | Tyr | Gly | Ser | Phe | Phe | 380 |
| Lys | Thr | Ile | Asp | Gly | Ile | Met | Ala | Tyr | His | Gln | Glu | Pro | Pro | Gly | Lys | 400 |
| Glu | Asn | Glu | Thr | Asp | Arg | Glu | Ala | Gly | Lys | Asn | Ile | Thr | Leu | Asp | Ile | 415 |
| Met | Arg | Glu | Lys | Val | Pro | Tyr | Ile | Tyr | Arg | Lys | Leu | Leu | Pro | Ile | Glu | 430 |
| Asp | Ser | His | Ile | Asn | Arg | Val | Pro | Leu | Val | Ser | Ile | Tyr | Ile | Pro | Ala | 445 |
| Tyr | Asn | Cys | Ala | Asn | Tyr | Ile | Gln | Arg | Cys | Val | Asp | Ser | Ala | Leu | Asn | 460 |
| Gln | Thr | Val | Val | Asp | Leu | Glu | Val | Cys | Ile | Cys | Asn | Asp | Gly | Ser | Thr | 480 |
| Asp | Asn | Thr | Leu | Glu | Val | Ile | Asn | Lys | Leu | Tyr | Gly | Asn | Asn | Pro | Arg | 495 |
| Val | Arg | Ile | Met | Ser | Lys | Pro | Asn | Gly | Gly | Ile | Ala | Ser | Ala | Ser | Asn | 510 |
| Ala | Ala | Val | Ser | Phe | Ala | Lys | Gly | Tyr | Tyr | Ile | Gly | Gln | Leu | Asp | Ser | 525 |
| Asp | Asp | Tyr | Leu | Glu | Pro | Asp | Ala | Val | Glu | Leu | Cys | Leu | Lys | Glu | Phe | 540 |
| Leu | Lys | Asp | Lys | Thr | Leu | Ala | Cys | Val | Tyr | Thr | Thr | Asn | Arg | Asn | Val | 560 |

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| | | | | | | | | | | | | | | | |
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| Asn | Pro | Asp | Gly | Ser | Leu | Ile | Ala | Asn | Gly | Tyr | Asn | Trp | Pro | Glu | Phe |
| | | | | 565 | | | | | 570 | | | | | 575 | |
| Ser | Arg | Glu | Lys | Leu | Thr | Thr | Ala | Met | Ile | Ala | His | His | Phe | Arg | Met |
| | | | 580 | | | | | 585 | | | | | 590 | | |
| Phe | Thr | Ile | Arg | Ala | Trp | His | Leu | Thr | Asp | Gly | Phe | Asn | Glu | Lys | Ile |
| | | 595 | | | | | 600 | | | | | 605 | | | |
| Glu | Asn | Ala | Val | Asp | Tyr | Asp | Met | Phe | Leu | Lys | Leu | Ser | Glu | Val | Gly |
| | 610 | | | | | 615 | | | | | 620 | | | | |
| Lys | Phe | Lys | His | Leu | Asn | Lys | Ile | Cys | Tyr | Asn | Arg | Val | Leu | His | Gly |
| 625 | | | | | 630 | | | | | 635 | | | | | 640 |
| Asp | Asn | Thr | Ser | Ile | Lys | Lys | Leu | Gly | Ile | Gln | Lys | Lys | Asn | His | Phe |
| | | | | 645 | | | | | 650 | | | | | 655 | |
| Val | Val | Val | Asn | Gln | Ser | Leu | Asn | Arg | Gln | Gly | Ile | Thr | Tyr | Tyr | Asn |
| | | | 660 | | | | | 665 | | | | | 670 | | |
| Tyr | Asp | Glu | Phe | Asp | Asp | Leu | Asp | Glu | Ser | Arg | Lys | Tyr | Ile | Phe | Asn |
| | | 675 | | | | | 680 | | | | | | 685 | | |
| Lys | Thr | Ala | Glu | Tyr | Gln | Glu | Glu | Ile | Asp | Ile | Leu | Lys | Asp | Ile | Lys |
| | 690 | | | | | 695 | | | | | 700 | | | | |
| Ile | Ile | Gln | Asn | Lys | Asp | Ala | Lys | Ile | Ala | Val | Ser | Ile | Phe | Tyr | Pro |
| 705 | | | | | 710 | | | | | 715 | | | | | 720 |
| Asn | Thr | Leu | Asn | Gly | Leu | Val | Lys | Lys | Leu | Asn | Asn | Ile | Ile | Glu | Tyr |
| | | | | 725 | | | | | 730 | | | | | 735 | |
| Asn | Lys | Asn | Ile | Phe | Val | Ile | Val | Leu | His | Val | Asp | Lys | Asn | His | Leu |
| | | | 740 | | | | | 745 | | | | | 750 | | |
| Thr | Pro | Asp | Ile | Lys | Lys | Glu | Ile | Leu | Ala | Phe | Tyr | His | Lys | His | Gln |
| | | 755 | | | | 760 | | | | | | 765 | | | |
| Val | Asn | Ile | Leu | Leu | Asn | Asn | Asp | Ile | Ser | Tyr | Tyr | Thr | Ser | Asn | Arg |
| | 770 | | | | | 775 | | | | | 780 | | | | |
| Leu | Ile | Lys | Thr | Glu | Ala | His | Leu | Ser | Asn | Ile | Asn | Lys | Leu | Ser | Gln |
| 785 | | | | | 790 | | | | | 795 | | | | | 800 |
| Leu | Asn | Leu | Asn | Cys | Glu | Tyr | Ile | Ile | Phe | Asp | Asn | His | Asp | Ser | Leu |
| | | | | 805 | | | | | 810 | | | | | 815 | |
| Phe | Val | Lys | Asn | Asp | Ser | Tyr | Ala | Tyr | Met | Lys | Lys | Tyr | Asp | Val | Gly |
| | | | 820 | | | | | 825 | | | | | 830 | | |
| Met | Asn | Phe | Ser | Ala | Leu | Thr | His | Asp | Trp | Ile | Glu | Lys | Ile | Asn | Ala |
| | | 835 | | | | | 840 | | | | | 845 | | | |
| His | Pro | Pro | Phe | Lys | Lys | Leu | Ile | Lys | Thr | Tyr | Phe | Asn | Asp | Asn | Asp |
| | 850 | | | | | 855 | | | | | 860 | | | | |
| Leu | Lys | Ser | Met | Asn | Val | Lys | Gly | Ala | Ser | Gln | Gly | Met | Phe | Met | Thr |
| 865 | | | | | 870 | | | | | 875 | | | | | 880 |
| Tyr | Ala | Leu | Ala | His | Glu | Leu | Leu | Thr | Ile | Ile | Lys | Glu | Val | Ile | Thr |
| | | | | 885 | | | | | 890 | | | | | 895 | |
| Ser | Cys | Gln | Ser | Ile | Asp | Ser | Val | Pro | Glu | Tyr | Asn | Thr | Glu | Asp | Ile |
| | | | 900 | | | | | 905 | | | | | 910 | | |
| Trp | Phe | Gln | Phe | Ala | Leu | Leu | Ile | Leu | Glu | Lys | Lys | Thr | Gly | His | Val |
| | | 915 | | | | | 920 | | | | | | 925 | | |
| Phe | Asn | Lys | Thr | Ser | Thr | Leu | Thr | Tyr | Met | Pro | Trp | Glu | Arg | Lys | Leu |
| | 930 | | | | | 935 | | | | | 940 | | | | |
| Gln | Trp | Thr | Asn | Glu | Gln | Ile | Glu | Ser | Ala | Lys | Arg | Gly | Glu | Asn | Ile |
| 945 | | | | | 950 | | | | | 955 | | | | | 960 |
| Pro | Val | Asn | Lys | Phe | Ile | Ile | Asn | Ser | Ile | Thr | Leu | | | | |
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gtt ctt tta tca ctt caa aac gaa gtc act att gtt gat att ctt ccc      96
Val Leu Leu Ser Leu Gln Asn Glu Val Thr Ile Val Asp Ile Leu Pro
          20           25           30

tct aaa gtt gat aag att aat aat ggc tta tca cca att caa gat gaa     144
Ser Lys Val Asp Lys Ile Asn Asn Gly Leu Ser Pro Ile Gln Asp Glu
          35           40           45

tat att gaa tat tac tta aaa agt aag caa tta tct att aaa gca act     192
Tyr Ile Glu Tyr Tyr Leu Lys Ser Lys Gln Leu Ser Ile Lys Ala Thr
          50           55           60

tta gat agc aaa gca gct tat aaa gaa gcg gaa ctg gtc att att gcc     240
Leu Asp Ser Lys Ala Ala Tyr Lys Glu Ala Glu Leu Val Ile Ile Ala
65           70           75           80

aca cct aca aat tac aac agt aga att aat tat ttt gat aca cag cat     288
Thr Pro Thr Asn Tyr Asn Ser Arg Ile Asn Tyr Phe Asp Thr Gln His
          85           90           95

gtt gaa aca gtt atc aaa gag gta cta agc gtt aat agc cat gca act     336
Val Glu Thr Val Ile Lys Glu Val Leu Ser Val Asn Ser His Ala Thr
          100          105          110

ctt atc atc aaa tca aca att cca ata ggt ttc att act gaa atg aga     384
Leu Ile Ile Lys Ser Thr Ile Pro Ile Gly Phe Ile Thr Glu Met Arg
          115          120          125

cag aaa ttc caa act gat cgt att atc ttc agc cct gaa ttt tta aga     432
Gln Lys Phe Gln Thr Asp Arg Ile Ile Phe Ser Pro Glu Phe Leu Arg
          130          135          140

gaa tct aaa gct tta tat gac aac tta tat cca agc cga att att gtt     480
Glu Ser Lys Ala Leu Tyr Asp Asn Leu Tyr Pro Ser Arg Ile Ile Val
145          150          155          160

tct tgt gaa gaa aac gat tct cca aaa gta aag gca gac gca gaa aaa     528
Ser Cys Glu Glu Asn Asp Ser Pro Lys Val Lys Ala Asp Ala Glu Lys
          165          170          175

ttt gca ctt tta tta aag tct gca gct aaa aaa aat aat gta cca gta     576
Phe Ala Leu Leu Leu Lys Ser Ala Ala Lys Lys Asn Asn Val Pro Val
          180          185          190

ctt att atg gga gct tca gaa gct gaa gca gta aaa cta ttt gcc aat     624
Leu Ile Met Gly Ala Ser Glu Ala Glu Ala Val Lys Leu Phe Ala Asn
          195          200          205

act tat tta gcg tta agg gta gct tat ttt aat gag tta gac act tac     672
Thr Tyr Leu Ala Leu Arg Val Ala Tyr Phe Asn Glu Leu Asp Thr Tyr
          210          215          220

gca gaa tcg aga aaa tta aat agt cac atg att att caa gga att tct     720
Ala Glu Ser Arg Lys Leu Asn Ser His Met Ile Ile Gln Gly Ile Ser
225          230          235          240

tat gat gat cga ata gga atg cat tat aat aac cca tca ttt ggt tat     768
Tyr Asp Asp Arg Ile Gly Met His Tyr Asn Asn Pro Ser Phe Gly Tyr
          245          250          255

gga ggt tat tgt cta cct aaa gat acg aag caa tta ttg gca aat tac     816
Gly Gly Tyr Cys Leu Pro Lys Asp Thr Lys Gln Leu Leu Ala Asn Tyr
          260          265          270

aat aat att cct caa acg cta att gaa gct atc gtt tca tca aat aat     864
Asn Asn Ile Pro Gln Thr Leu Ile Glu Ala Ile Val Ser Ser Asn Asn
          275          280          285

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| | |
|---|------|
| gtg cgc aag tcc tat att gct aag caa att atc aac gtc tta gaa gag | 912 |
| Val Arg Lys Ser Tyr Ile Ala Lys Gln Ile Ile Asn Val Leu Glu Glu | |
| 290 295 300 | |
| | |
| cgg gag tcc cca gta aaa gta gtc ggg gtt tac cgt tta att atg aaa | 960 |
| Arg Glu Ser Pro Val Lys Val Val Gly Val Tyr Arg Leu Ile Met Lys | |
| 305 310 315 320 | |
| | |
| agt aac tca gat aat ttt aga gaa agt gct atc aaa gat gtt att gac | 1008 |
| Ser Asn Ser Asp Asn Phe Arg Glu Ser Ala Ile Lys Asp Val Ile Asp | |
| 325 330 335 | |
| | |
| att ctt aaa agt aaa gac att aag ata att att tat gag cca atg tta | 1056 |
| Ile Leu Lys Ser Lys Asp Ile Lys Ile Ile Ile Tyr Glu Pro Met Leu | |
| 340 345 350 | |
| | |
| aac aaa ctt gaa tct gaa gat caa tct gta ctt gta aat gat tta gag | 1104 |
| Asn Lys Leu Glu Ser Glu Asp Gln Ser Val Leu Val Asn Asp Leu Glu | |
| 355 360 365 | |
| | |
| aat ttc aag aaa caa gca aat att atc gta act aat cgc tat gat aat | 1152 |
| Asn Phe Lys Lys Gln Ala Asn Ile Ile Val Thr Asn Arg Tyr Asp Asn | |
| 370 375 380 | |
| | |
| gaa tta caa gat gtt aaa aat aaa gtt tac agt aga gat att ttt aat | 1200 |
| Glu Leu Gln Asp Val Lys Asn Lys Val Tyr Ser Arg Asp Ile Phe Asn | |
| 385 390 395 400 | |
| | |
| aga gac | 1206 |
| Arg Asp | |

<210> SEQ ID NO 97

<211> LENGTH: 402

<212> TYPE: PRT

<213> ORGANISM: Streptococcus pyogenes

<400> SEQUENCE: 97

| | |
|---|--|
| Met Lys Ile Ala Val Ala Gly Ser Gly Tyr Val Gly Leu Ser Leu Gly | |
| 1 5 10 15 | |
| Val Leu Leu Ser Leu Gln Asn Glu Val Thr Ile Val Asp Ile Leu Pro | |
| 20 25 30 | |
| Ser Lys Val Asp Lys Ile Asn Asn Gly Leu Ser Pro Ile Gln Asp Glu | |
| 35 40 45 | |
| Tyr Ile Glu Tyr Tyr Leu Lys Ser Lys Gln Leu Ser Ile Lys Ala Thr | |
| 50 55 60 | |
| Leu Asp Ser Lys Ala Ala Tyr Lys Glu Ala Glu Leu Val Ile Ile Ala | |
| 65 70 75 80 | |
| Thr Pro Thr Asn Tyr Asn Ser Arg Ile Asn Tyr Phe Asp Thr Gln His | |
| 85 90 95 | |
| Val Glu Thr Val Ile Lys Glu Val Leu Ser Val Asn Ser His Ala Thr | |
| 100 105 110 | |
| Leu Ile Ile Lys Ser Thr Ile Pro Ile Gly Phe Ile Thr Glu Met Arg | |
| 115 120 125 | |
| Gln Lys Phe Gln Thr Asp Arg Ile Ile Phe Ser Pro Glu Phe Leu Arg | |
| 130 135 140 | |
| Glu Ser Lys Ala Leu Tyr Asp Asn Leu Tyr Pro Ser Arg Ile Ile Val | |
| 145 150 155 160 | |
| Ser Cys Glu Glu Asn Asp Ser Pro Lys Val Lys Ala Asp Ala Glu Lys | |
| 165 170 175 | |
| Phe Ala Leu Leu Leu Lys Ser Ala Ala Lys Lys Asn Asn Val Pro Val | |
| 180 185 190 | |
| Leu Ile Met Gly Ala Ser Glu Ala Glu Ala Val Lys Leu Phe Ala Asn | |
| 195 200 205 | |
| Thr Tyr Leu Ala Leu Arg Val Ala Tyr Phe Asn Glu Leu Asp Thr Tyr | |

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| 210 | 215 | 220 |
|--|-----|-----|
| Ala Glu Ser Arg Lys Leu Asn Ser His Met Ile Ile Gln Gly Ile Ser 225 230 235 240 | | |
| Tyr Asp Asp Arg Ile Gly Met His Tyr Asn Asn Pro Ser Phe Gly Tyr 245 250 255 | | |
| Gly Gly Tyr Cys Leu Pro Lys Asp Thr Lys Gln Leu Leu Ala Asn Tyr 260 265 270 | | |
| Asn Asn Ile Pro Gln Thr Leu Ile Glu Ala Ile Val Ser Ser Asn Asn 275 280 285 | | |
| Val Arg Lys Ser Tyr Ile Ala Lys Gln Ile Ile Asn Val Leu Glu Glu 290 295 300 | | |
| Arg Glu Ser Pro Val Lys Val Val Gly Val Tyr Arg Leu Ile Met Lys 305 310 315 320 | | |
| Ser Asn Ser Asp Asn Phe Arg Glu Ser Ala Ile Lys Asp Val Ile Asp 325 330 335 | | |
| Ile Leu Lys Ser Lys Asp Ile Lys Ile Ile Ile Tyr Glu Pro Met Leu 340 345 350 | | |
| Asn Lys Leu Glu Ser Glu Asp Gln Ser Val Leu Val Asn Asp Leu Glu 355 360 365 | | |
| Asn Phe Lys Lys Gln Ala Asn Ile Ile Val Thr Asn Arg Tyr Asp Asn 370 375 380 | | |
| Glu Leu Gln Asp Val Lys Asn Lys Val Tyr Ser Arg Asp Ile Phe Asn 385 390 395 400 | | |

Arg Asp

<210> SEQ ID NO 98
 <211> LENGTH: 912
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus pyogenes
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(912)

<400> SEQUENCE: 98

| | |
|---|-----|
| atg acc aaa gtc aga aaa gcc att att cct gct gca ggt cta gga aca Met Thr Lys Val Arg Lys Ala Ile Ile Pro Ala Ala Gly Leu Gly Thr 1 5 10 15 | 48 |
| cgt ttt tta cct gct acc aaa gct ctt gcc aaa gag atg ttg ccc atc Arg Phe Leu Pro Ala Thr Lys Ala Leu Ala Lys Glu Met Leu Pro Ile 20 25 30 | 96 |
| gtt gat aaa cca acc atc cag ttt atc gtc gaa gaa gcg cta aaa tct Val Asp Lys Pro Thr Ile Gln Phe Ile Val Glu Glu Ala Leu Lys Ser 35 40 45 | 144 |
| ggc atc gag gaa atc ctt gtg gtg acc gga aaa gct aaa cgc tct atc Gly Ile Glu Glu Ile Leu Val Val Thr Gly Lys Ala Lys Arg Ser Ile 50 55 60 | 192 |
| gag gac cat ttt gat tca aac ttt gaa tta gaa tac aac ctc caa gct Glu Asp His Phe Asp Ser Asn Phe Glu Leu Glu Tyr Asn Leu Gln Ala 65 70 75 80 | 240 |
| aag ggg aaa aat gaa ctg ttg aaa tta gtg gat gaa acc act gcc att Lys Gly Lys Asn Glu Leu Leu Lys Leu Val Asp Glu Thr Thr Ala Ile 85 90 95 | 288 |
| aac ctt cat ttt atc cgt caa agc cac cca aga ggg ctg gga gat gct Asn Leu His Phe Ile Arg Gln Ser His Pro Arg Gly Leu Gly Asp Ala 100 105 110 | 336 |
| gtc tta caa gcc aaa gcc ttt gtg ggc aat gaa ccc ttt gtg gtc atg Val Leu Gln Ala Lys Ala Phe Val Gly Asn Glu Pro Phe Val Val Met 115 120 125 | 384 |

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| | |
|---|-----|
| ctt gga gat gac tta atg gac att aca aat gca tcc gct aaa cct ctc | 432 |
| Leu Gly Asp Asp Leu Met Asp Ile Thr Asn Ala Ser Ala Lys Pro Leu | |
| 130 135 140 | |
| acc aaa caa ctc atg gag gac tat gac aag acg cat gca tcc act atc | 480 |
| Thr Lys Gln Leu Met Glu Asp Tyr Asp Lys Thr His Ala Ser Thr Ile | |
| 145 150 155 160 | |
| gct gtg atg aaa gtt cct cat gaa gat gtg tct agc tat ggg gtt atc | 528 |
| Ala Val Met Lys Val Pro His Glu Asp Val Ser Ser Tyr Gly Val Ile | |
| 165 170 175 | |
| gct cct caa ggc aag gct gtc aag ggc ctt tac agt gta gac acc ttt | 576 |
| Ala Pro Gln Gly Lys Ala Val Lys Gly Leu Tyr Ser Val Asp Thr Phe | |
| 180 185 190 | |
| gtt gaa aaa cca caa cca gaa gat gcg cct agt gat ttg gct att att | 624 |
| Val Glu Lys Pro Gln Pro Glu Asp Ala Pro Ser Asp Leu Ala Ile Ile | |
| 195 200 205 | |
| ggt cgt tac ctc cta acc cct gaa att ttt ggt att ttg gaa aga cag | 672 |
| Gly Arg Tyr Leu Leu Thr Pro Glu Ile Phe Gly Ile Leu Glu Arg Gln | |
| 210 215 220 | |
| acc cct gga gca ggt aac gaa gtg caa ctc aca gat gct atc gat acc | 720 |
| Thr Pro Gly Ala Gly Asn Glu Val Gln Leu Thr Asp Ala Ile Asp Thr | |
| 225 230 235 240 | |
| ctc aat aaa act cag cgt gtc ttt gca cga gaa ttt aaa ggc aat cgt | 768 |
| Leu Asn Lys Thr Gln Arg Val Phe Ala Arg Glu Phe Lys Gly Asn Arg | |
| 245 250 255 | |
| tac gat gtt ggg gat aaa ttt gga ttc atg aaa aca tct atc gac tat | 816 |
| Tyr Asp Val Gly Asp Lys Phe Gly Phe Met Lys Thr Ser Ile Asp Tyr | |
| 260 265 270 | |
| gcc tta gaa cac cca cag gtc aaa gag gac ttg aaa aat tac att atc | 864 |
| Ala Leu Glu His Pro Gln Val Lys Glu Asp Leu Lys Asn Tyr Ile Ile | |
| 275 280 285 | |
| aaa cta gga aaa gct ttg gaa aaa agt aaa gta cca aca cat tca aag | 912 |
| Lys Leu Gly Lys Ala Leu Glu Lys Ser Lys Val Pro Thr His Ser Lys | |
| 290 295 300 | |

<210> SEQ ID NO 99

<211> LENGTH: 304

<212> TYPE: PRT

<213> ORGANISM: Streptococcus pyogenes

<400> SEQUENCE: 99

| | |
|---|--|
| Met Thr Lys Val Arg Lys Ala Ile Ile Pro Ala Ala Gly Leu Gly Thr | |
| 1 5 10 15 | |
| Arg Phe Leu Pro Ala Thr Lys Ala Leu Ala Lys Glu Met Leu Pro Ile | |
| 20 25 30 | |
| Val Asp Lys Pro Thr Ile Gln Phe Ile Val Glu Glu Ala Leu Lys Ser | |
| 35 40 45 | |
| Gly Ile Glu Glu Ile Leu Val Val Thr Gly Lys Ala Lys Arg Ser Ile | |
| 50 55 60 | |
| Glu Asp His Phe Asp Ser Asn Phe Glu Leu Glu Tyr Asn Leu Gln Ala | |
| 65 70 75 80 | |
| Lys Gly Lys Asn Glu Leu Leu Lys Leu Val Asp Glu Thr Thr Ala Ile | |
| 85 90 95 | |
| Asn Leu His Phe Ile Arg Gln Ser His Pro Arg Gly Leu Gly Asp Ala | |
| 100 105 110 | |
| Val Leu Gln Ala Lys Ala Phe Val Gly Asn Glu Pro Phe Val Val Met | |
| 115 120 125 | |
| Leu Gly Asp Asp Leu Met Asp Ile Thr Asn Ala Ser Ala Lys Pro Leu | |
| 130 135 140 | |
| Thr Lys Gln Leu Met Glu Asp Tyr Asp Lys Thr His Ala Ser Thr Ile | |

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| 145 | 150 | 155 | 160 |
|---|-----|-----|-----|
| Ala Val Met Lys Val Pro His Glu Asp Val Ser Ser Tyr Gly Val Ile | 165 | 170 | 175 |
| Ala Pro Gln Gly Lys Ala Val Lys Gly Leu Tyr Ser Val Asp Thr Phe | 180 | 185 | 190 |
| Val Glu Lys Pro Gln Pro Glu Asp Ala Pro Ser Asp Leu Ala Ile Ile | 195 | 200 | 205 |
| Gly Arg Tyr Leu Leu Thr Pro Glu Ile Phe Gly Ile Leu Glu Arg Gln | 210 | 215 | 220 |
| Thr Pro Gly Ala Gly Asn Glu Val Gln Leu Thr Asp Ala Ile Asp Thr | 225 | 230 | 235 |
| Leu Asn Lys Thr Gln Arg Val Phe Ala Arg Glu Phe Lys Gly Asn Arg | 245 | 250 | 255 |
| Tyr Asp Val Gly Asp Lys Phe Gly Phe Met Lys Thr Ser Ile Asp Tyr | 260 | 265 | 270 |
| Ala Leu Glu His Pro Gln Val Lys Glu Asp Leu Lys Asn Tyr Ile Ile | 275 | 280 | 285 |
| Lys Leu Gly Lys Ala Leu Glu Lys Ser Lys Val Pro Thr His Ser Lys | 290 | 295 | 300 |

<210> SEQ ID NO 100

<211> LENGTH: 1347

<212> TYPE: DNA

<213> ORGANISM: Streptococcus equi zooepidemicus

<220> FEATURE:

<221> NAME/KEY: CDS

<222> LOCATION: (1)..(1347)

<400> SEQUENCE: 100

| | |
|---|-----|
| atg tca cat att aca ttt gat tat tca aag gtt ctt gag caa ttt gcc | 48 |
| Met Ser His Ile Thr Phe Asp Tyr Ser Lys Val Leu Glu Gln Phe Ala | 15 |
| 1 5 10 | |
| gga cag cat gaa att gac ttt tta caa ggt cag gta aca gag gct gat | 96 |
| Gly Gln His Glu Ile Asp Phe Leu Gln Gly Gln Val Thr Glu Ala Asp | 30 |
| 20 25 | |
| cag gca cta cgt cag ggc act gga cct gga tca gat ttc ttg ggc tgg | 144 |
| Gln Ala Leu Arg Gln Gly Thr Gly Pro Gly Ser Asp Phe Leu Gly Trp | 45 |
| 35 40 | |
| ctt gag tta cct gaa aac tat gac aaa gaa gaa ttt gct cgt atc ctt | 192 |
| Leu Glu Leu Pro Glu Asn Tyr Asp Lys Glu Glu Phe Ala Arg Ile Leu | 60 |
| 50 55 60 | |
| aaa gca gct gag aag att aag gct gac agt gac gtt ctt gtt gtg att | 240 |
| Lys Ala Ala Glu Lys Ile Lys Ala Asp Ser Asp Val Leu Val Val Ile | 80 |
| 65 70 75 80 | |
| ggt att ggt ggc tct tac ctt ggt gct aag gct gca att gac ttt ttg | 288 |
| Gly Ile Gly Gly Ser Tyr Leu Gly Ala Lys Ala Ala Ile Asp Phe Leu | 95 |
| 85 90 95 | |
| aac agc cat ttt gcc aac cta caa aca gca aaa gag cgc aaa gca cca | 336 |
| Asn Ser His Phe Ala Asn Leu Gln Thr Ala Lys Glu Arg Lys Ala Pro | 110 |
| 100 105 110 | |
| caa att ctt tat gct ggt aac tcc atc tca tca agc tat ctt gct gat | 384 |
| Gln Ile Leu Tyr Ala Gly Asn Ser Ile Ser Ser Ser Tyr Leu Ala Asp | 125 |
| 115 120 125 | |
| ctt gtg gac tat gtt caa gat aaa gat ttc tct gtt aac gtg att tct | 432 |
| Leu Val Asp Tyr Val Gln Asp Lys Asp Phe Ser Val Asn Val Ile Ser | 140 |
| 130 135 140 | |
| aag tct ggt aca aca aca gag cct gca atc gcc ttt cgt gtc ttt aaa | 480 |
| Lys Ser Gly Thr Thr Thr Glu Pro Ala Ile Ala Phe Arg Val Phe Lys | 160 |
| 145 150 155 160 | |

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| | |
|---|------|
| gaa tta ctt gtt aaa aag tac ggt caa gaa gag gcc aac aag cgt atc Glu Leu Leu Val Lys Lys Tyr Gly Gln Glu Glu Ala Asn Lys Arg Ile 165 170 175 | 528 |
| tat gca acg act gat aag gtc aag ggt gct gtt aag gtt gag gct gat Tyr Ala Thr Thr Asp Lys Val Lys Gly Ala Val Lys Val Glu Ala Asp 180 185 190 | 576 |
| gca aat cat tgg gaa acc ttt gtt gtg cca gat aat gtt ggt ggc cgt Ala Asn His Trp Glu Thr Phe Val Val Pro Asp Asn Val Gly Gly Arg 195 200 205 | 624 |
| ttc tca gtg ctg aca gct gtg ggc ttg cta cca att gca gca tca ggg Phe Ser Val Leu Thr Ala Val Gly Leu Leu Pro Ile Ala Ala Ser Gly 210 215 220 | 672 |
| gct gat att acc gcg ctg atg gaa gga gca aat gca gct cgt aag gac Ala Asp Ile Thr Ala Leu Met Glu Gly Ala Asn Ala Ala Arg Lys Asp 225 230 235 240 | 720 |
| ctg tca tca gat aaa atc tca gaa aac atc gct tac caa tat gct gtg Leu Ser Ser Asp Lys Ile Ser Glu Asn Ile Ala Tyr Gln Tyr Ala Val 245 250 255 | 768 |
| gtc cgc aat atc ctc tat cgc aaa ggc tat gta act gaa att ttg gca Val Arg Asn Ile Leu Tyr Arg Lys Gly Tyr Val Thr Glu Ile Leu Ala 260 265 270 | 816 |
| aac tat gag cca tca ttg cag tat ttt agc gaa tgg tgg aag caa ctg Asn Tyr Glu Pro Ser Leu Gln Tyr Phe Ser Glu Trp Trp Lys Gln Leu 275 280 285 | 864 |
| gct ggt gag tct gaa gga aag gac caa aag ggt att tac cca act tca Ala Gly Glu Ser Glu Gly Lys Asp Gln Lys Gly Ile Tyr Pro Thr Ser 290 295 300 | 912 |
| gct aat ttc tcg aca gac ctg cat tct ctt ggt caa ttt atc caa gaa Ala Asn Phe Ser Thr Asp Leu His Ser Leu Gly Gln Phe Ile Gln Glu 305 310 315 320 | 960 |
| ggc tac cgt aac ctc ttt gag aca gtg att cgt gtg gac aag cca cgt Gly Tyr Arg Asn Leu Phe Glu Thr Val Ile Arg Val Asp Lys Pro Arg 325 330 335 | 1008 |
| caa aat gtg att atc cca gaa atg gct gag gac ctt gat ggc ctt ggc Gln Asn Val Ile Ile Pro Glu Met Ala Glu Asp Leu Asp Gly Leu Gly 340 345 350 | 1056 |
| tac cta caa gga aaa gac gtt gac ttt gtc aac aaa aaa gca aca gat Tyr Leu Gln Gly Lys Asp Val Asp Phe Val Asn Lys Lys Ala Thr Asp 355 360 365 | 1104 |
| ggt gtc ctt ctt gcc cat aca gat ggt ggt gtg cca aat atg ttt atc Gly Val Leu Leu Ala His Thr Asp Gly Gly Val Pro Asn Met Phe Ile 370 375 380 | 1152 |
| acg ctt cca gag caa gac gaa ttt aca cta ggc tat acg atc tac ttc Thr Leu Pro Glu Gln Asp Glu Phe Thr Leu Gly Tyr Thr Ile Tyr Phe 385 390 395 400 | 1200 |
| ttt gag ctt gct att gcc ctt tca ggc tac ctc aac ggg gtc aat cca Phe Glu Leu Ala Ile Ala Leu Ser Gly Tyr Leu Asn Gly Val Asn Pro 405 410 415 | 1248 |
| ttt gat cag cca ggc gtt gag gct tac aag aaa aac atg ttt gcc ctt Phe Asp Gln Pro Gly Val Glu Ala Tyr Lys Lys Asn Met Phe Ala Leu 420 425 430 | 1296 |
| ctt ggt aag cca ggc ttt gaa gag cta gga gca gcg ctc aac gca cgc Leu Gly Lys Pro Gly Phe Glu Glu Leu Gly Ala Ala Leu Asn Ala Arg 435 440 445 | 1344 |
| ttg Leu | 1347 |

<210> SEQ ID NO 101

<211> LENGTH: 449

<212> TYPE: PRT

<213> ORGANISM: Streptococcus equi zooepidemicus

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<400> SEQUENCE: 101

Met Ser His Ile Thr Phe Asp Tyr Ser Lys Val Leu Glu Gln Phe Ala
 1 5 10 15
 Gly Gln His Glu Ile Asp Phe Leu Gln Gly Gln Val Thr Glu Ala Asp
 20 25 30
 Gln Ala Leu Arg Gln Gly Thr Gly Pro Gly Ser Asp Phe Leu Gly Trp
 35 40 45
 Leu Glu Leu Pro Glu Asn Tyr Asp Lys Glu Glu Phe Ala Arg Ile Leu
 50 55 60
 Lys Ala Ala Glu Lys Ile Lys Ala Asp Ser Asp Val Leu Val Val Ile
 65 70 75 80
 Gly Ile Gly Gly Ser Tyr Leu Gly Ala Lys Ala Ala Ile Asp Phe Leu
 85 90 95
 Asn Ser His Phe Ala Asn Leu Gln Thr Ala Lys Glu Arg Lys Ala Pro
 100 105 110
 Gln Ile Leu Tyr Ala Gly Asn Ser Ile Ser Ser Ser Tyr Leu Ala Asp
 115 120 125
 Leu Val Asp Tyr Val Gln Asp Lys Asp Phe Ser Val Asn Val Ile Ser
 130 135 140
 Lys Ser Gly Thr Thr Thr Glu Pro Ala Ile Ala Phe Arg Val Phe Lys
 145 150 155 160
 Glu Leu Leu Val Lys Lys Tyr Gly Gln Glu Glu Ala Asn Lys Arg Ile
 165 170 175
 Tyr Ala Thr Thr Asp Lys Val Lys Gly Ala Val Lys Val Glu Ala Asp
 180 185 190
 Ala Asn His Trp Glu Thr Phe Val Val Pro Asp Asn Val Gly Gly Arg
 195 200 205
 Phe Ser Val Leu Thr Ala Val Gly Leu Leu Pro Ile Ala Ala Ser Gly
 210 215 220
 Ala Asp Ile Thr Ala Leu Met Glu Gly Ala Asn Ala Ala Arg Lys Asp
 225 230 235 240
 Leu Ser Ser Asp Lys Ile Ser Glu Asn Ile Ala Tyr Gln Tyr Ala Val
 245 250 255
 Val Arg Asn Ile Leu Tyr Arg Lys Gly Tyr Val Thr Glu Ile Leu Ala
 260 265 270
 Asn Tyr Glu Pro Ser Leu Gln Tyr Phe Ser Glu Trp Trp Lys Gln Leu
 275 280 285
 Ala Gly Glu Ser Glu Gly Lys Asp Gln Lys Gly Ile Tyr Pro Thr Ser
 290 295 300
 Ala Asn Phe Ser Thr Asp Leu His Ser Leu Gly Gln Phe Ile Gln Glu
 305 310 315 320
 Gly Tyr Arg Asn Leu Phe Glu Thr Val Ile Arg Val Asp Lys Pro Arg
 325 330 335
 Gln Asn Val Ile Ile Pro Glu Met Ala Glu Asp Leu Asp Gly Leu Gly
 340 345 350
 Tyr Leu Gln Gly Lys Asp Val Asp Phe Val Asn Lys Lys Ala Thr Asp
 355 360 365
 Gly Val Leu Leu Ala His Thr Asp Gly Gly Val Pro Asn Met Phe Ile
 370 375 380
 Thr Leu Pro Glu Gln Asp Glu Phe Thr Leu Gly Tyr Thr Ile Tyr Phe
 385 390 395 400
 Phe Glu Leu Ala Ile Ala Leu Ser Gly Tyr Leu Asn Gly Val Asn Pro
 405 410 415

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Phe Asp Gln Pro Gly Val Glu Ala Tyr Lys Lys Asn Met Phe Ala Leu
 420 425 430

Leu Gly Lys Pro Gly Phe Glu Glu Leu Gly Ala Ala Leu Asn Ala Arg
 435 440 445

Leu

<210> SEQ ID NO 102
 <211> LENGTH: 1251
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus uberis
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(1251)

<400> SEQUENCE: 102

| | |
|---|-----|
| atg gaa aaa cta aaa aat ctc att aca ttt atg act ttt att ttc ctg | 48 |
| Met Glu Lys Leu Lys Asn Leu Ile Thr Phe Met Thr Phe Ile Phe Leu | |
| 1 5 10 15 | |
| tgg ctc ata att att ggg ctt aat gtt ttt gta ttt gga act aaa gga | 96 |
| Trp Leu Ile Ile Ile Gly Leu Asn Val Phe Val Phe Gly Thr Lys Gly | |
| 20 25 30 | |
| agt cta aca gtg tat ggg att att cta tta acc tat ttg tcg ata aaa | 144 |
| Ser Leu Thr Val Tyr Gly Ile Ile Leu Leu Thr Tyr Leu Ser Ile Lys | |
| 35 40 45 | |
| atg gga tta tct ttt ttt tat cgt ccc tat aaa gga agt gta ggt caa | 192 |
| Met Gly Leu Ser Phe Phe Tyr Arg Pro Tyr Lys Gly Ser Val Gly Gln | |
| 50 55 60 | |
| tat aag gta gca gct att atc cca tct tat aat gag gat ggt gtc ggt | 240 |
| Tyr Lys Val Ala Ala Ile Ile Pro Ser Tyr Asn Glu Asp Gly Val Gly | |
| 65 70 75 80 | |
| tta cta gaa act cta aag agt gtt caa aaa caa aca tat cca att gca | 288 |
| Leu Leu Glu Thr Leu Lys Ser Val Gln Lys Gln Thr Tyr Pro Ile Ala | |
| 85 90 95 | |
| gaa att ttc gta att gac gat ggg tca gta gat aaa aca ggt ata aaa | 336 |
| Glu Ile Phe Val Ile Asp Asp Gly Ser Val Asp Lys Thr Gly Ile Lys | |
| 100 105 110 | |
| ttg gtc gaa gac tat gtg aag tta aat ggc ttt gga gac caa gtt atc | 384 |
| Leu Val Glu Asp Tyr Val Lys Leu Asn Gly Phe Gly Asp Gln Val Ile | |
| 115 120 125 | |
| gtt cat cag atg cct gaa aat gtt ggt aaa aga cat gct cag gct tgg | 432 |
| Val His Gln Met Pro Glu Asn Val Gly Lys Arg His Ala Gln Ala Trp | |
| 130 135 140 | |
| gca ttt gaa agg tct gat gct gat gtt ttc tta aca gtg gat tca gat | 480 |
| Ala Phe Glu Arg Ser Asp Ala Asp Val Phe Leu Thr Val Asp Ser Asp | |
| 145 150 155 160 | |
| acc tac atc tat cct gat gct ctt gaa gaa tta tta aag aca ttt aat | 528 |
| Thr Tyr Ile Tyr Pro Asp Ala Leu Glu Glu Leu Leu Lys Thr Phe Asn | |
| 165 170 175 | |
| gat cca gag gtc tac gct gca act ggt cat tta aat gca aga aat aga | 576 |
| Asp Pro Glu Val Tyr Ala Ala Thr Gly His Leu Asn Ala Arg Asn Arg | |
| 180 185 190 | |
| caa act aat ctc tta act aga ctg act gat att cgt tac gat aat gca | 624 |
| Gln Thr Asn Leu Leu Thr Arg Leu Thr Asp Ile Arg Tyr Asp Asn Ala | |
| 195 200 205 | |
| ttt ggt gta gaa cgt gct gct cag tct gtt acg gga aat att ttg gtt | 672 |
| Phe Gly Val Glu Arg Ala Ala Gln Ser Val Thr Gly Asn Ile Leu Val | |
| 210 215 220 | |
| tgt tcc gga cct tta agt att tat aga cgt tcc gtc ggt att cca aat | 720 |
| Cys Ser Gly Pro Leu Ser Ile Tyr Arg Arg Ser Val Gly Ile Pro Asn | |
| 225 230 235 240 | |

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| | |
|---|------|
| ctt gaa cgc tat acc tca caa aca ttt ctt ggt gtc cct gta agc ata | 768 |
| Leu Glu Arg Tyr Thr Ser Gln Thr Phe Leu Gly Val Pro Val Ser Ile | |
| 245 250 255 | |
| ggg gat gac cgt tgt ttg aca aat tat gca act gat ttg gga aaa acg | 816 |
| Gly Asp Asp Arg Cys Leu Thr Asn Tyr Ala Thr Asp Leu Gly Lys Thr | |
| 260 265 270 | |
| ggt tat cag tca act gca aga tgt gat act gac gtt cca gat aag ttt | 864 |
| Val Tyr Gln Ser Thr Ala Arg Cys Asp Thr Asp Val Pro Asp Lys Phe | |
| 275 280 285 | |
| aag gtt ttc atc aaa caa caa aat cgt tgg aat aag tca ttt ttt agg | 912 |
| Lys Val Phe Ile Lys Gln Gln Asn Arg Trp Asn Lys Ser Phe Phe Arg | |
| 290 295 300 | |
| gag tct att atc tct gtt aag aag tta tta gcc aca cca agt gtt gct | 960 |
| Glu Ser Ile Ile Ser Val Lys Lys Leu Leu Ala Thr Pro Ser Val Ala | |
| 305 310 315 320 | |
| ggt tgg act att aca gaa gtt tcc atg ttc atc atg cta gtt tat tct | 1008 |
| Val Trp Thr Ile Thr Glu Val Ser Met Phe Ile Met Leu Val Tyr Ser | |
| 325 330 335 | |
| atc ttt agc tta ttg ata gga gag gct caa gaa ttt aat ctc ata aaa | 1056 |
| Ile Phe Ser Leu Leu Ile Gly Glu Ala Gln Glu Phe Asn Leu Ile Lys | |
| 340 345 350 | |
| ctg gtt gct ttt tta gtt att att ttc ata gta gct ctt tgt aga aat | 1104 |
| Leu Val Ala Phe Leu Val Ile Ile Phe Ile Val Ala Leu Cys Arg Asn | |
| 355 360 365 | |
| ggt cat tac atg gtt aag cat cca ttt gct ttt tta ttg tca ccg ttt | 1152 |
| Val His Tyr Met Val Lys His Pro Phe Ala Phe Leu Leu Ser Pro Phe | |
| 370 375 380 | |
| tat gga ttg ata cat cta ttc gtt ttg caa cct ctt aag ata tat tcg | 1200 |
| Tyr Gly Leu Ile His Leu Phe Val Leu Gln Pro Leu Lys Ile Tyr Ser | |
| 385 390 395 400 | |
| tta ttt act ata aga aat gct aca tgg gga act cgt aaa aag aca agt | 1248 |
| Leu Phe Thr Ile Arg Asn Ala Thr Trp Gly Thr Arg Lys Lys Thr Ser | |
| 405 410 415 | |
| aaa | 1251 |
| Lys | |

<210> SEQ ID NO 103

<211> LENGTH: 417

<212> TYPE: PRT

<213> ORGANISM: Streptococcus uberis

<400> SEQUENCE: 103

| | |
|---|--|
| Met Glu Lys Leu Lys Asn Leu Ile Thr Phe Met Thr Phe Ile Phe Leu | |
| 1 5 10 15 | |
| Trp Leu Ile Ile Ile Gly Leu Asn Val Phe Val Phe Gly Thr Lys Gly | |
| 20 25 30 | |
| Ser Leu Thr Val Tyr Gly Ile Ile Leu Leu Thr Tyr Leu Ser Ile Lys | |
| 35 40 45 | |
| Met Gly Leu Ser Phe Phe Tyr Arg Pro Tyr Lys Gly Ser Val Gly Gln | |
| 50 55 60 | |
| Tyr Lys Val Ala Ala Ile Ile Pro Ser Tyr Asn Glu Asp Gly Val Gly | |
| 65 70 75 80 | |
| Leu Leu Glu Thr Leu Lys Ser Val Gln Lys Gln Thr Tyr Pro Ile Ala | |
| 85 90 95 | |
| Glu Ile Phe Val Ile Asp Asp Gly Ser Val Asp Lys Thr Gly Ile Lys | |
| 100 105 110 | |
| Leu Val Glu Asp Tyr Val Lys Leu Asn Gly Phe Gly Asp Gln Val Ile | |
| 115 120 125 | |
| Val His Gln Met Pro Glu Asn Val Gly Lys Arg His Ala Gln Ala Trp | |

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| | | | | |
|-------------------------|---|-----|--|-----|
| 130 | 135 | 140 | | |
| Ala Phe Glu Arg Ser Asp | Ala Asp Val Phe Leu Thr Val Asp Ser Asp | | | |
| 145 | 150 | 155 | | 160 |
| Thr Tyr Ile Tyr Pro Asp | Ala Leu Glu Glu Leu Leu Lys Thr Phe Asn | | | |
| | 165 | 170 | | 175 |
| Asp Pro Glu Val Tyr Ala | Ala Thr Gly His Leu Asn Ala Arg Asn Arg | | | |
| | 180 | 185 | | 190 |
| Gln Thr Asn Leu Leu Thr | Arg Leu Thr Asp Ile Arg Tyr Asp Asn Ala | | | |
| | 195 | 200 | | 205 |
| Phe Gly Val Glu Arg Ala | Ala Gln Ser Val Thr Gly Asn Ile Leu Val | | | |
| | 210 | 215 | | 220 |
| Cys Ser Gly Pro Leu Ser | Ile Tyr Arg Arg Ser Val Gly Ile Pro Asn | | | |
| 225 | 230 | 235 | | 240 |
| Leu Glu Arg Tyr Thr Ser | Gln Thr Phe Leu Gly Val Pro Val Ser Ile | | | |
| | 245 | 250 | | 255 |
| Gly Asp Asp Arg Cys Leu | Thr Asn Tyr Ala Thr Asp Leu Gly Lys Thr | | | |
| | 260 | 265 | | 270 |
| Val Tyr Gln Ser Thr Ala | Arg Cys Asp Thr Asp Val Pro Asp Lys Phe | | | |
| | 275 | 280 | | 285 |
| Lys Val Phe Ile Lys Gln | Gln Asn Arg Trp Asn Lys Ser Phe Phe Arg | | | |
| | 290 | 295 | | 300 |
| Glu Ser Ile Ile Ser Val | Lys Lys Leu Leu Ala Thr Pro Ser Val Ala | | | |
| 305 | 310 | 315 | | 320 |
| Val Trp Thr Ile Thr Glu | Val Ser Met Phe Ile Met Leu Val Tyr Ser | | | |
| | 325 | 330 | | 335 |
| Ile Phe Ser Leu Leu Ile | Gly Glu Ala Gln Glu Phe Asn Leu Ile Lys | | | |
| | 340 | 345 | | 350 |
| Leu Val Ala Phe Leu Val | Ile Ile Phe Ile Val Ala Leu Cys Arg Asn | | | |
| | 355 | 360 | | 365 |
| Val His Tyr Met Val Lys | His Pro Phe Ala Phe Leu Leu Ser Pro Phe | | | |
| | 370 | 375 | | 380 |
| Tyr Gly Leu Ile His Leu | Phe Val Leu Gln Pro Leu Lys Ile Tyr Ser | | | |
| 385 | 390 | 395 | | 400 |
| Leu Phe Thr Ile Arg Asn | Ala Thr Trp Gly Thr Arg Lys Lys Thr Ser | | | |
| | 405 | 410 | | 415 |

Lys

<210> SEQ ID NO 104
 <211> LENGTH: 1203
 <212> TYPE: DNA
 <213> ORGANISM: Streptococcus uberis
 <220> FEATURE:
 <221> NAME/KEY: CDS
 <222> LOCATION: (1)..(1203)

<400> SEQUENCE: 104

| | |
|---|-----|
| gtg aaa att gca gtt gca ggt tct ggc tat gtt ggc cta tca tta agt | 48 |
| Val Lys Ile Ala Val Ala Gly Ser Gly Tyr Val Gly Leu Ser Leu Ser | |
| 1 5 10 15 | |
| gta tta tta gca cag aaa aat cct gtt aca gtt gta gat att att gag | 96 |
| Val Leu Leu Ala Gln Lys Asn Pro Val Thr Val Val Asp Ile Ile Glu | |
| 20 25 30 | |
| aag aaa gta aat ctc ata aat caa aaa caa tca cca atc cag gat gtt | 144 |
| Lys Lys Val Asn Leu Ile Asn Gln Lys Gln Ser Pro Ile Gln Asp Val | |
| 35 40 45 | |
| gat att gaa aac tat tta aaa gaa aaa aag tta caa tta aga gct act | 192 |
| Asp Ile Glu Asn Tyr Leu Lys Glu Lys Lys Leu Gln Leu Arg Ala Thr | |

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| 50 | 55 | 60 | |
|---|----|----|------|
| cta gac gcc gat caa gca ttt agg gat gca gat ata cta att att gct Leu Asp Ala Asp Gln Ala Phe Arg Asp Ala Asp Ile Leu Ile Ile Ala 65 70 75 80 | | | 240 |
| aca cca acc aat tat gat gtg gag aag aat ttt ttt gat act agt cat Thr Pro Thr Asn Tyr Asp Val Glu Lys Asn Phe Phe Asp Thr Ser His 85 90 95 | | | 288 |
| gtt gag act gta att gag aaa gct tta gct tta aat agt cag gct ttg Val Glu Thr Val Ile Glu Lys Ala Leu Ala Leu Asn Ser Gln Ala Leu 100 105 110 | | | 336 |
| tta gtt att aaa tca acg ata cca ctt ggt ttt att aaa aag atg cgt Leu Val Ile Lys Ser Thr Ile Pro Leu Gly Phe Ile Lys Lys Met Arg 115 120 125 | | | 384 |
| caa aaa tat cag aca gac cgt att att ttt agt ccc gaa ttt ctt aga Gln Lys Tyr Gln Thr Asp Arg Ile Ile Phe Ser Pro Glu Phe Leu Arg 130 135 140 | | | 432 |
| gag tct aaa gct tta aaa gat aat ctt tat cct agt cga ata att gtt Glu Ser Lys Ala Leu Lys Asp Asn Leu Tyr Pro Ser Arg Ile Ile Val 145 150 155 160 | | | 480 |
| tcc ttt gaa gat gat gat tct atg gaa gta ata gaa gca gca aag act Ser Phe Glu Asp Asp Asp Ser Met Glu Val Ile Glu Ala Ala Lys Thr 165 170 175 | | | 528 |
| ttt gct caa ttg tta aaa gat ggt tct ttg gat aaa gat gtt cct gta Phe Ala Gln Leu Leu Lys Asp Gly Ser Leu Asp Lys Asp Val Pro Val 180 185 190 | | | 576 |
| ctt ttt atg ggt tca gca gag gct gaa gca gta aaa tta ttt gcc aat Leu Phe Met Gly Ser Ala Glu Ala Glu Ala Val Lys Leu Phe Ala Asn 195 200 205 | | | 624 |
| acc tat tta gct atg cgt gtc tcc tat ttt aat gag tta gat aca tat Thr Tyr Leu Ala Met Arg Val Ser Tyr Phe Asn Glu Leu Asp Thr Tyr 210 215 220 | | | 672 |
| gct gaa aag aat ggt tta cgt gtg gat aat att att gag ggc gtt tgc Ala Glu Lys Asn Gly Leu Arg Val Asp Asn Ile Ile Glu Gly Val Cys 225 230 235 240 | | | 720 |
| cat gat cga cgc ata gga att cat tat aat aac cct tct ttt ggc tat His Asp Arg Arg Ile Gly Ile His Tyr Asn Asn Pro Ser Phe Gly Tyr 245 250 255 | | | 768 |
| gga gga tac tgc tta cct aaa gat acc aaa cag ttg cta gca ggc tat Gly Gly Tyr Cys Leu Pro Lys Asp Thr Lys Gln Leu Leu Ala Gly Tyr 260 265 270 | | | 816 |
| gat ggt att cct caa tcg ctt ata aaa gca att gtt gat tct aat aaa Asp Gly Ile Pro Gln Ser Leu Ile Lys Ala Ile Val Asp Ser Asn Lys 275 280 285 | | | 864 |
| att cgt aaa gag tat atc gca tca caa att tta caa caa ttg agt gat Ile Arg Lys Glu Tyr Ile Ala Ser Gln Ile Leu Gln Gln Leu Ser Asp 290 295 300 | | | 912 |
| att aat gta gat cct aaa gat gca acg att ggt att tac cgc ctt atc Ile Asn Val Asp Pro Lys Asp Ala Thr Ile Gly Ile Tyr Arg Leu Ile 305 310 315 320 | | | 960 |
| atg aaa agt aac tct gat aat ttc aga gag agt gca ata aaa gat att Met Lys Ser Asn Ser Asp Asn Phe Arg Glu Ser Ala Ile Lys Asp Ile 325 330 335 | | | 1008 |
| att gat cat att aag agc tat caa att aat ata gtc ttg tat gag cca Ile Asp His Ile Lys Ser Tyr Gln Ile Asn Ile Val Leu Tyr Glu Pro 340 345 350 | | | 1056 |
| atg atg aat gaa gat ttt gat tta cca atc att gat gat tta tct gac Met Met Asn Glu Asp Phe Asp Leu Pro Ile Ile Asp Asp Leu Ser Asp 355 360 365 | | | 1104 |
| ttc aaa gcc atg tca cat att atc gtt tca aat aga tat gat tta gcc Phe Lys Ala Met Ser His Ile Ile Val Ser Asn Arg Tyr Asp Leu Ala | | | 1152 |

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| 370 | 375 | 380 | |
|---|-----|-----|------|
| tta gaa gat gtt aaa gaa aaa gtt tac acc aga gat att tac ggt gtg | | | 1200 |
| Leu Glu Asp Val Lys Glu Lys Val Tyr Thr Arg Asp Ile Tyr Gly Val | | | |
| 385 | 390 | 395 | 400 |
| gat | | | 1203 |
| Asp | | | |
| <210> SEQ ID NO 105 | | | |
| <211> LENGTH: 401 | | | |
| <212> TYPE: PRT | | | |
| <213> ORGANISM: Streptococcus uberis | | | |
| <400> SEQUENCE: 105 | | | |
| Val Lys Ile Ala Val Ala Gly Ser Gly Tyr Val Gly Leu Ser Leu Ser | | | |
| 1 | 5 | 10 | 15 |
| Val Leu Leu Ala Gln Lys Asn Pro Val Thr Val Val Asp Ile Ile Glu | | | |
| | 20 | 25 | 30 |
| Lys Lys Val Asn Leu Ile Asn Gln Lys Gln Ser Pro Ile Gln Asp Val | | | |
| | 35 | 40 | 45 |
| Asp Ile Glu Asn Tyr Leu Lys Glu Lys Lys Leu Gln Leu Arg Ala Thr | | | |
| | 50 | 55 | 60 |
| Leu Asp Ala Asp Gln Ala Phe Arg Asp Ala Asp Ile Leu Ile Ile Ala | | | |
| | 65 | 70 | 75 |
| Thr Pro Thr Asn Tyr Asp Val Glu Lys Asn Phe Phe Asp Thr Ser His | | | |
| | 85 | 90 | 95 |
| Val Glu Thr Val Ile Glu Lys Ala Leu Ala Leu Asn Ser Gln Ala Leu | | | |
| | 100 | 105 | 110 |
| Leu Val Ile Lys Ser Thr Ile Pro Leu Gly Phe Ile Lys Lys Met Arg | | | |
| | 115 | 120 | 125 |
| Gln Lys Tyr Gln Thr Asp Arg Ile Ile Phe Ser Pro Glu Phe Leu Arg | | | |
| | 130 | 135 | 140 |
| Glu Ser Lys Ala Leu Lys Asp Asn Leu Tyr Pro Ser Arg Ile Ile Val | | | |
| | 145 | 150 | 155 |
| Ser Phe Glu Asp Asp Asp Ser Met Glu Val Ile Glu Ala Ala Lys Thr | | | |
| | 165 | 170 | 175 |
| Phe Ala Gln Leu Leu Lys Asp Gly Ser Leu Asp Lys Asp Val Pro Val | | | |
| | 180 | 185 | 190 |
| Leu Phe Met Gly Ser Ala Glu Ala Glu Ala Val Lys Leu Phe Ala Asn | | | |
| | 195 | 200 | 205 |
| Thr Tyr Leu Ala Met Arg Val Ser Tyr Phe Asn Glu Leu Asp Thr Tyr | | | |
| | 210 | 215 | 220 |
| Ala Glu Lys Asn Gly Leu Arg Val Asp Asn Ile Ile Glu Gly Val Cys | | | |
| | 225 | 230 | 235 |
| His Asp Arg Arg Ile Gly Ile His Tyr Asn Asn Pro Ser Phe Gly Tyr | | | |
| | 245 | 250 | 255 |
| Gly Gly Tyr Cys Leu Pro Lys Asp Thr Lys Gln Leu Leu Ala Gly Tyr | | | |
| | 260 | 265 | 270 |
| Asp Gly Ile Pro Gln Ser Leu Ile Lys Ala Ile Val Asp Ser Asn Lys | | | |
| | 275 | 280 | 285 |
| Ile Arg Lys Glu Tyr Ile Ala Ser Gln Ile Leu Gln Gln Leu Ser Asp | | | |
| | 290 | 295 | 300 |
| Ile Asn Val Asp Pro Lys Asp Ala Thr Ile Gly Ile Tyr Arg Leu Ile | | | |
| | 305 | 310 | 315 |
| Met Lys Ser Asn Ser Asp Asn Phe Arg Glu Ser Ala Ile Lys Asp Ile | | | |
| | 325 | 330 | 335 |

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Ile Asp His Ile Lys Ser Tyr Gln Ile Asn Ile Val Leu Tyr Glu Pro
      340                      345                      350

Met Met Asn Glu Asp Phe Asp Leu Pro Ile Ile Asp Asp Leu Ser Asp
      355                      360                      365

Phe Lys Ala Met Ser His Ile Ile Val Ser Asn Arg Tyr Asp Leu Ala
      370                      375                      380

Leu Glu Asp Val Lys Glu Lys Val Tyr Thr Arg Asp Ile Tyr Gly Val
385                      390                      395                      400

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Asp

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<210> SEQ ID NO 106
<211> LENGTH: 912
<212> TYPE: DNA
<213> ORGANISM: Streptococcus uberis
<220> FEATURE:
<221> NAME/KEY: CDS
<222> LOCATION: (1)..(912)

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<400> SEQUENCE: 106

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atg act aaa gta aga aaa gcc att att cca gct gcc gga ctt ggc aca      48
Met Thr Lys Val Arg Lys Ala Ile Ile Pro Ala Ala Gly Leu Gly Thr
1                      5                      10                      15

cgt ttt tta cca gca aca aaa gct ctc gct aag gaa atg ttg ccc atc      96
Arg Phe Leu Pro Ala Thr Lys Ala Leu Ala Lys Glu Met Leu Pro Ile
      20                      25                      30

gtt gac aaa cca acc att caa ttc atc gtg gaa gaa gct ttg cgt tct     144
Val Asp Lys Pro Thr Ile Gln Phe Ile Val Glu Glu Ala Leu Arg Ser
      35                      40                      45

ggc att gaa gaa atc ttg gtc gta aca gga aaa tca aaa cgc tcc att     192
Gly Ile Glu Glu Ile Leu Val Val Thr Gly Lys Ser Lys Arg Ser Ile
      50                      55                      60

gaa gac cat ttt gat tcc aac ttt gaa ctc gaa tat aat ttg caa gaa     240
Glu Asp His Phe Asp Ser Asn Phe Glu Leu Glu Tyr Asn Leu Gln Glu
65                      70                      75                      80

aaa ggg aaa act gaa ctc tta aaa tta gtt gat gaa acc act tct ata     288
Lys Gly Lys Thr Glu Leu Leu Lys Leu Val Asp Glu Thr Thr Ser Ile
      85                      90                      95

aac ttg cat ttc att cgt caa agt cat ccc aaa ggc tta ggg gat gct     336
Asn Leu His Phe Ile Arg Gln Ser His Pro Lys Gly Leu Gly Asp Ala
      100                      105                      110

gtt tta caa gca aaa gct ttt gta gga aat gaa ccc ttc att gtt atg     384
Val Leu Gln Ala Lys Ala Phe Val Gly Asn Glu Pro Phe Ile Val Met
      115                      120                      125

ctt ggt gac gat ttg atg gac att aca aat acc aaa gct gtc cca tta     432
Leu Gly Asp Asp Leu Met Asp Ile Thr Asn Thr Lys Ala Val Pro Leu
      130                      135                      140

acc aaa caa tta atg gac gat tat gaa aca aca cat gct tct aca ata     480
Thr Lys Gln Leu Met Asp Asp Tyr Glu Thr Thr His Ala Ser Thr Ile
145                      150                      155                      160

gcc gta atg aaa gtt cct cac gat gac gta tcc tct tat ggt gtc att     528
Ala Val Met Lys Val Pro His Asp Asp Val Ser Ser Tyr Gly Val Ile
      165                      170                      175

gct cca aac ggc aaa gcc ttg aat ggc tta tat agc gtg gat acc ttt     576
Ala Pro Asn Gly Lys Ala Leu Asn Gly Leu Tyr Ser Val Asp Thr Phe
      180                      185                      190

gtt gaa aaa cca aaa cct gag gac gca cca agt gac ctt gct atc att     624
Val Glu Lys Pro Lys Pro Glu Asp Ala Pro Ser Asp Leu Ala Ile Ile
      195                      200                      205

gga cgt tat ctc tta aca cct gaa att ttt gac att ctt gaa aat caa     672
Gly Arg Tyr Leu Leu Thr Pro Glu Ile Phe Asp Ile Leu Glu Asn Gln
      210                      215                      220

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gca cca ggt gcc gga aac gaa gtc caa tta act gat gct atc gat acc 720
Ala Pro Gly Ala Gly Asn Glu Val Gln Leu Thr Asp Ala Ile Asp Thr
225                230                235                240

ctc aac aaa aca caa cgt gtt ttt gct cgt gag ttt act ggc aaa cgc 768
Leu Asn Lys Thr Gln Arg Val Phe Ala Arg Glu Phe Thr Gly Lys Arg
                245                250                255

tac gat gtt gga gac aag ttt ggc ttc atg aaa aca tct atc gat tat 816
Tyr Asp Val Gly Asp Lys Phe Gly Phe Met Lys Thr Ser Ile Asp Tyr
                260                265                270

gcc cta aaa cac cat caa gtc aaa gat gac cta aaa gct tat att atc 864
Ala Leu Lys His His Gln Val Lys Asp Asp Leu Lys Ala Tyr Ile Ile
                275                280                285

aag tta ggt aaa gaa tta gaa aaa gca caa gat tcc aaa gaa agc aaa 912
Lys Leu Gly Lys Glu Leu Glu Lys Ala Gln Asp Ser Lys Glu Ser Lys
290                295                300

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<210> SEQ ID NO 107
<211> LENGTH: 304
<212> TYPE: PRT
<213> ORGANISM: Streptococcus uberis

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<400> SEQUENCE: 107

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Met Thr Lys Val Arg Lys Ala Ile Ile Pro Ala Ala Gly Leu Gly Thr
1                5                10                15

Arg Phe Leu Pro Ala Thr Lys Ala Leu Ala Lys Glu Met Leu Pro Ile
                20                25                30

Val Asp Lys Pro Thr Ile Gln Phe Ile Val Glu Glu Ala Leu Arg Ser
35                40                45

Gly Ile Glu Glu Ile Leu Val Val Thr Gly Lys Ser Lys Arg Ser Ile
50                55                60

Glu Asp His Phe Asp Ser Asn Phe Glu Leu Glu Tyr Asn Leu Gln Glu
65                70                75                80

Lys Gly Lys Thr Glu Leu Leu Lys Leu Val Asp Glu Thr Thr Ser Ile
85                90                95

Asn Leu His Phe Ile Arg Gln Ser His Pro Lys Gly Leu Gly Asp Ala
100               105               110

Val Leu Gln Ala Lys Ala Phe Val Gly Asn Glu Pro Phe Ile Val Met
115               120               125

Leu Gly Asp Asp Leu Met Asp Ile Thr Asn Thr Lys Ala Val Pro Leu
130               135               140

Thr Lys Gln Leu Met Asp Asp Tyr Glu Thr Thr His Ala Ser Thr Ile
145               150               155               160

Ala Val Met Lys Val Pro His Asp Asp Val Ser Ser Tyr Gly Val Ile
165               170               175

Ala Pro Asn Gly Lys Ala Leu Asn Gly Leu Tyr Ser Val Asp Thr Phe
180               185               190

Val Glu Lys Pro Lys Pro Glu Asp Ala Pro Ser Asp Leu Ala Ile Ile
195               200               205

Gly Arg Tyr Leu Leu Thr Pro Glu Ile Phe Asp Ile Leu Glu Asn Gln
210               215               220

Ala Pro Gly Ala Gly Asn Glu Val Gln Leu Thr Asp Ala Ile Asp Thr
225               230               235               240

Leu Asn Lys Thr Gln Arg Val Phe Ala Arg Glu Phe Thr Gly Lys Arg
245               250               255

Tyr Asp Val Gly Asp Lys Phe Gly Phe Met Lys Thr Ser Ile Asp Tyr
260               265               270

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Ala Leu Lys His His Gln Val Lys Asp Asp Leu Lys Ala Tyr Ile Ile
 275 280 285

Lys Leu Gly Lys Glu Leu Glu Lys Ala Gln Asp Ser Lys Glu Ser Lys
 290 295 300

<210> SEQ ID NO 108

<211> LENGTH: 5158

<212> TYPE: DNA

<213> ORGANISM: *Streptococcus equisimilis*

<400> SEQUENCE: 108

tcaatttatg gctttttgct gatagcttac ctattagtca aaatgtcctt atcctttttt 60
 tacaagccat ttaaggaag ggctgggcaa tataagggtg cagccattat tcctcttat 120
 aacgaagatg ctgagtcatt gctagagacc ttaaaaagtg ttcagcagca aacctatccc 180
 ctgacagaaa tttatgttgt tgacgatgga agtgctgatg agacaggtat taagcgcatt 240
 gaagactatg tgcgtgacac tggtgacctt tcaagcaatg tcattgttca tcggtcagag 300
 aaaaatcaag gaaagcgtca tgcacaggcc tgggcctttg aaagatcaga cgctgatgctc 360
 tttttgaccg ttgactcaga tacttatatc taccctgatg ctttagagga gttgttaaaa 420
 acctttaatg acccaactgt ttttgctgcg acgggtcacc ttaatgtcag aaatagacaa 480
 accaatctct taacacgctt gacagatatt cgctatgata atgcttttgg cgttgaacga 540
 gctgcccaat ccgttacagg taatatacct gtttgcctcag gtccgcttag cgtttacaga 600
 cgcgaggtgg ttgttcctaa catagataga tacatcaacc agaccttctt gggattcct 660
 gtaagtattg gtgatgacag gtgcttgacc aactatgcaa ctgatttagg aaagactggt 720
 tatcaatcca ctgctaaatg tattacagat gttcctgaca agatgtctac ttacttgaag 780
 cagcaaaaacc gctggaacaa gtccttcttt agagagtcca ttatttctgt taagaaaatc 840
 atgaacaatc cttttgtagc cctatggacc atacttgagg tgtctatggt tatgatgctt 900
 gtttattctg tgggtgattt ctttgtaggc aatgtcagag aatttgattg gctcaggggt 960
 ttgaccttct tgggtgattt cttcattggt gccctgtgct ggaacattca ttacatgctt 1020
 aagcaccocg tgccttctt gttatctccg ttttatgggg tgctgcattt gtttgcctta 1080
 cagcccttga aattatattc tctttttact attagaaatg ctgactgggg aacacgtaaa 1140
 aaattattat aaaccaacta gacctagggt ctgacaaggg agctaagcta gggataaaca 1200
 aagagttttg atccgactcg agcagctcat aaacgaaagc tatcccactt gtaattgaag 1260
 ctaagagctt ttagcttgca gctctataaa gacgaaccag aggctgagtg tcagctttgg 1320
 tgtgagggct aggtcattat gatccttcag gtgtggcacc tgagctccgg cagtagctaa 1380
 ctgtactaag gtatcaaagg aaaaaatgaa gtgaaaattt ctgtagcagg ctcaggatat 1440
 gtcggcctat ccttgagtat tttactggca caacataatg acgtcactgt tgttgacatt 1500
 attgatgaaa aggtgagatt gatcaatcaa ggcatatcgc caatcaagga tgctgatatt 1560
 gaggagtatt taaaaaatgc gccgctaaat ctcacagcga cgcttgatgg cgcaagcgct 1620
 tatagcaatg cagaccttat tatcattgct actccgacaa attatgacag cgaacgcaac 1680
 tactttgaca caaggcatgt tgaagaggtc atcgagcagg tcctagacct aaatgcgtca 1740
 gcaaccatta ttatcaaatc aaccatacca ctaggcttta tcaagcatgt tagggaaaaa 1800
 taccagacag atcgtattat ttttagccca gaatttttaa gagaatcaaa agccttatac 1860
 gataaccttt acccaagtcg gatcattggt tcttatgaaa aggacgactc accaaggggt 1920
 attcaggctg ctaaagcctt tgctggctct ttaaaggaag gagccaaaag caaggatact 1980

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| | | | | | | |
|------------|------------|-------------|-------------|------------|-------------|------|
| ccggtcttat | ttatgggctc | acaggaggct | gaggcggtea | agctatttgc | gaataccttt | 2040 |
| ttggctatgc | gggtgtctta | ctttaatgaa | ttagacacct | attccgaaag | caagggctca | 2100 |
| gatgctcagc | gcgtgattga | aggagtctgt | catgatcagc | gcattggtaa | ccattacaat | 2160 |
| aacccttctc | ttggatatgg | cggtatttgc | ctgccaaagg | acagcaagca | gctgttggca | 2220 |
| aattatagag | gcattcccca | gtccttgatg | tcagcgattg | ttgaatcca | caagatacga | 2280 |
| aatcttatt | tggtgaaca | aatattagac | agagcctcta | gtcaaaagca | ggctgggtga | 2340 |
| ccattaacga | ttggctttta | ccgcttgatt | atgaaaagca | actctgataa | tttccgagaa | 2400 |
| agcgccatta | aagatattat | tgatatcatc | aacgactatg | gggttaatat | tgctatttac | 2460 |
| gaacccatgc | ttggcgagga | tattggctac | agggttgtca | aggacttaga | gcagttcaaa | 2520 |
| aacgagtcta | caatcattgt | gtcaaatcgc | tttgaggacg | acctaggaga | tgctattgat | 2580 |
| aaggtttata | cgagagatgt | ctttggaaga | gactagttag | aaaacgaatg | gcaactcataa | 2640 |
| ggaaccacaa | atcaaggagg | aactcatgac | aaaggtcaga | aaagccatta | tcccagccgc | 2700 |
| cggcctaggg | actcgttcc | tgcccggcac | caaggcaactg | gccaaggaaa | tgctcccaat | 2760 |
| cgctgataag | ccaaccattc | aattcatcgt | cgaggaagcc | ctaaaggcag | gtatcgagga | 2820 |
| gattcttgtc | gtcaccggca | aggccaaacg | ctctatcgag | gaccactttg | actccaactt | 2880 |
| cgagctcgaa | tacaatctcc | aagccaaggg | caaaaccgag | ctactcaagc | tcgttgatga | 2940 |
| gaccactgcc | atcaacctgc | acttcattcg | tcagagccac | cctagaggac | taggggacgc | 3000 |
| tgctctcaa | gccaaggcct | ttgttgga | tgagcccttt | gtggctatgc | tgggggatga | 3060 |
| cctcatggat | attaccaatc | ctagtgccaa | gcccttgacc | aagcagctta | ttgaggatta | 3120 |
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| ttatggtgtg | attgcaccgc | aaggggaaggc | tgtaagggc | ttgtatagtg | tgagagacctt | 3240 |
| tggtgagaag | ccaagtccag | atgaggcacc | gagtgactta | gagattattg | gtcgatattt | 3300 |
| gttgacgect | gagatttttg | ccatattgga | gaagcagggc | cctggagctg | gcaatgaggt | 3360 |
| acagctgacc | gatgcgattg | acaagctcaa | taagacacag | cggttttttg | cgagggagtt | 3420 |
| taagggagag | cggtatgatg | ttggggacaa | gtttggcttt | atgaagacct | cacttgacta | 3480 |
| tgctctcaag | caccctcagg | tcaaggacga | cctcactgac | tacattataa | agctcagtaa | 3540 |
| gcaactgaac | aaggacgtca | agaaataggc | gttattgat | cagctattgc | agagctattt | 3600 |
| aaaagcattt | agagctttaa | gggtgggatac | tagaggattg | gtatctcact | ttttaggctg | 3660 |
| acttgatta | ataccaaaag | ccaaaactag | gcagataagc | ataaggaatt | agattaaaaa | 3720 |
| taaggaacca | aaacatgaaa | aactacgcca | ttatcctagc | agctggaaag | ggaacgcgca | 3780 |
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| cagagcaggt | gcgtgctgtc | ctaggagagc | aatcgctaac | agtggtgcaa | gaggagcagc | 3960 |
| tagggacagg | ccatgcagtc | atgatggcag | aagaggagct | atctggctta | gaggggcaaa | 4020 |
| ccctagtgat | tgaggtgac | acccccttga | tcagaggaga | aagcctcaag | gctctgctag | 4080 |
| actatcatat | cagagaaaag | aatgtggcaa | ccattctcac | agccaatgcc | aaggatccct | 4140 |
| ttggctatgg | acgaatcatt | cgcaatgcag | caggagaggt | ggcaacatc | gttgagcaaa | 4200 |
| aggatgctaa | tgaggcagag | caagaggctca | aggagatcaa | cacagggact | tatatctttg | 4260 |
| acaataagcg | cctttttgag | gctctaaagc | atctcacgac | tgataatgcc | caaggggagt | 4320 |
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| | | | | | | |
|------------|------------|------------|------------|-------------|------------|------|
| tgctgaagga | ctttgatgag | agcctagggg | ttaatgatcg | cttagctcta | gccagggccg | 4440 |
| aggtgattat | gcaagagcgg | atcaacaggc | agcacatgct | taatgggggtg | accctgcaaa | 4500 |
| accggcagc | tacctatatt | gaaagcagtg | tagagattgc | accagacgtc | ttgattgaag | 4560 |
| ccaatgtgac | cttaaaggga | cagactagaa | ttggcagcag | aagtgtcata | agcaatggga | 4620 |
| gctatatect | tgattcgagg | cttggtgagg | gtgtagtggt | tagccagtcg | gtgattgagg | 4680 |
| cttcagtctt | agcagatgga | gtgacagtag | ggccatatgc | acacattcgc | ccggactccc | 4740 |
| agctcgatga | gtgtgttcat | attgggaact | ttgtagaggt | taaggggtct | catctagggg | 4800 |
| ccaataccaa | ggcagggcat | ttgacttacc | tggggaatgc | cgagattggc | tcagaggtta | 4860 |
| acattggtgc | aggaagcatt | acggttaatt | atgatggtca | acggaaatac | cagacagtga | 4920 |
| ttggcgatca | cgtttttatt | gggagtcatt | cgactttgat | agctccggta | gaggttgggg | 4980 |
| agaatgcttt | aacagcagca | gggtctacga | tagcccagtc | agtgccggca | gacagtgtgg | 5040 |
| ctatagggcg | cagccgtcag | gtggtgaagg | aaggctatgc | caagaggctg | ccgcaccacc | 5100 |
| caaatcaagc | ctaategctc | aacaaaaaga | ggcaggtgag | aaaacctagg | ccattaaa | 5158 |

What is claimed is:

1. A method for producing a hyaluronic acid, comprising:
 - (a) cultivating a *Bacillus* host cell under conditions suitable for production of the hyaluronic acid, wherein the *Bacillus* host cell comprises an artificial operon comprising a short "consensus" amyQ promoter having the sequence TTGACA for the "-35" region and TATAAT for the "-10" region operably linked to a hyaluronan synthase encoding sequence, a UDP-glucose 6-dehydrogenase encoding sequence, and a UDP-glucose pyrophosphorylase encoding sequence;
 - wherein the hyaluronan synthase encoding sequence is (i) a nucleic acid sequence encoding a polypeptide comprising SEQ ID NO: 93; or (ii) a nucleic acid sequence which hybridizes under high stringency conditions with SEQ ID NO: 92 or its full-length complementary strand;
 - wherein the UDP-glucose 6-dehydrogenase encoding sequence is (i) a nucleic acid sequence encoding a polypeptide comprising SEQ ID NO: 12; or (ii) a nucleic acid sequence which hybridizes under high stringency conditions with SEQ ID NO: 11 or its full-length complementary strand;
 - wherein the UDP-glucose pyrophosphorylase encoding sequence is (i) a nucleic acid sequence encoding a polypeptide comprising SEQ ID NO: 22; or (ii) a nucleic acid sequence which hybridizes under high stringency conditions with SEQ ID NO: 21 or its full-length complementary strand; and
 - wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C.; and
 - (b) recovering the hyaluronic acid from the cultivation medium.
 2. The method of claim 1, wherein the hyaluronan synthase encoding sequence encodes a polypeptide comprising SEQ ID NO: 93.
 3. The method of claim 1, wherein the hyaluronan synthase encoding sequence is a nucleic acid sequence which hybridizes under high or very high stringency conditions with SEQ ID NO: 92 or its full-length complementary strand; wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C. and wherein very high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 70° C.
 4. The method of claim 1, wherein the UDP-glucose 6-dehydrogenase encoding sequence encodes a polypeptide comprising SEQ ID NO: 12.
 5. The method of claim 1, wherein the UDP-glucose 6-dehydrogenase encoding sequence is a nucleic acid sequence which hybridizes under high or very high stringency conditions with SEQ ID NO: 11 or its full-length complementary strand; wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C. and wherein very high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 70° C.
 6. The method of claim 1, wherein the UDP-glucose pyrophosphorylase encoding sequence encodes a polypeptide comprising SEQ ID NO: 22.
 7. The method of claim 1, wherein the UDP-glucose pyrophosphorylase encoding sequence is a nucleic acid sequence which hybridizes under high or very high stringency conditions with SEQ ID NO: 21 or its full-length complementary strand; wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C. and wherein very high stringency conditions are defined as

prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 70° C.

8. The method of claim 1, wherein the artificial operon further comprises one or more additional genes encoding enzymes in the biosynthesis of a precursor sugar of the hyaluronic acid or the *Bacillus* host cell further comprises one or more nucleic acid constructs comprising one or more additional genes encoding enzymes in the biosynthesis of a precursor sugar of the hyaluronic acid.

9. The method of claim 8, wherein the one or more additional genes encoding enzymes in the biosynthesis of a precursor sugar of the hyaluronic acid are selected from the group consisting of a UDP-N-acetylglucosamine pyrophosphorylase gene, glucose-6-phosphate isomerase gene, hexokinase gene, phosphoglucomutase gene, amidotransferase gene, mutase gene, and acetyl transferase gene.

10. The method of claim 9, wherein the UDP-N-acetylglucosamine pyrophosphorylase encoding sequence is (a) a nucleic acid sequence encoding a polypeptide comprising SEQ ID NO: 30; or (b) a nucleic acid sequence which hybridizes under high or very high stringency conditions with SEQ ID NO: 29 or its full-length complementary strand; wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C. and wherein very high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 70° C.

11. The method of claim 10, wherein the UDP-N-acetylglucosamine pyrophosphorylase encoding sequence encodes a polypeptide comprising SEQ ID NO: 30.

12. The method of claim 10, wherein the UDP-N-acetylglucosamine pyrophosphorylase encoding sequence is a nucleic acid sequence which hybridizes under high or very high stringency conditions with SEQ ID NO: 29 or its full-length complementary strand; wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C. and wherein very high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 70° C.

13. The method of claim 9, wherein the glucose-6-phosphate isomerase encoding sequence is (a) a nucleic acid sequence encoding a polypeptide comprising SEQ ID NO: 101; or (b) a nucleic acid sequence which hybridizes under high or very high stringency conditions with SEQ ID NO: 100 or its full-length complementary strand; wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and

washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C. and wherein very high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 70° C.

14. The method of claim 13, wherein the glucose-6-phosphate isomerase encoding sequence encodes a polypeptide comprising SEQ ID NO: 101.

15. The method of claim 13, wherein the glucose-6-phosphate isomerase encoding sequence is a nucleic acid sequence which hybridizes under high or very high stringency conditions with SEQ ID NO: 100 or its full-length complementary strand; wherein high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 65° C. and wherein very high stringency conditions are defined as prehybridization and hybridization at 42° C. in 5×SSPE, 0.3% SDS, 200 µg/ml sheared and denatured salmon sperm DNA, and 50% formamide, and washing three times each for 15 minutes using 2×SSC, 0.2% SDS preferably at least at 70° C.

16. The method of claim 9, wherein the one or more additional genes selected from the group of the UDP-N-acetylglucosamine pyrophosphorylase gene, glucose-6-phosphate isomerase gene, hexokinase gene, phosphoglucomutase gene, amidotransferase gene, mutase gene, and acetyl transferase gene are under the control of the same or a different promoter(s) as the hyaluronan synthase encoding sequence.

17. The method of claim 1, wherein the artificial operon further comprises an mRNA processing/stabilizing sequence located downstream of the short “consensus” amyQ promoter operably linked to the hyaluronan synthase encoding sequence, the UDP-glucose 6-dehydrogenase encoding sequence, and the UDP-glucose pyrophosphorylase encoding sequence and upstream of the hyaluronan synthase encoding sequence, the UDP-glucose 6-dehydrogenase encoding sequence, and the UDP-glucose pyrophosphorylase encoding sequence.

18. The method of claim 1, wherein the artificial operon further comprises a selectable marker gene.

19. The method of claim 1, wherein the *Bacillus* host cell is selected from the group consisting of *Bacillus agaradherens*, *Bacillus alkalophilus*, *Bacillus amyloliquefaciens*, *Bacillus brevis*, *Bacillus circulans*, *Bacillus clausii*, *Bacillus coagulans*, *Bacillus firmus*, *Bacillus lautus*, *Bacillus lentus*, *Bacillus licheniformis*, *Bacillus megaterium*, *Bacillus pumilus*, *Bacillus stearothermophilus*, *Bacillus subtilis*, and *Bacillus thuringiensis*.

20. The method of claim 1, wherein the *Bacillus* host cell is unmarked with a selectable marker.

21. The method of claim 1, wherein the artificial operon is integrated into the chromosome of the *Bacillus* host cell.

22. The method of claim 1, wherein the *Bacillus* host cell is a *Bacillus licheniformis* cell.

23. The method of claim 1, wherein the *Bacillus* host cell is a *Bacillus subtilis* cell.